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SCHOOL LABORATORY MANAGEMENT

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PREFACE

THE management of the laboratory is probably the most difficult duty the science master has to face, often made more difficult by the lack of satisfactory assistance, for not many schools can afford the expense of a full-time laboratory assistant. As a result, the majority of teachers of science have perforce to struggle with the sole help of some senior students, who, naturally, have received little, or no instruction in the care of the laboratory and its apparatus, nor even in the preparation of the necessary reagents. Many masters also, apart from one or two ideas gathered during their undergraduate days, have received no systematic training in these duties.

To overcome these and similar difficulties, the author was requested to give lectures to the graduates of the Cambridge University Training College for Schoolmasters, and it has been felt that the material of these lectures may be of some use to science-teachers generally.

The origin of the book indicates its purpose; the research worker will often have to use methods of greater refinement than those outlined; but the busy science master will find methods described which have been chosen to give as little trouble as possible whilst yielding results quite compatible with school laboratory conditions.

One branch of laboratory management seems to have been dealt with fully in other books, that of glass

manipulation and similar laboratory arts. The reader is therefore referred to the following books on this subject : *The Methods of Glass Blowing and of Working Silica in the Oxy-gas Flame*, by W. A. Shenstone ; *Laboratory Arts*, by G. H. Woollatt ; and *Laboratory Arts*, by R. Threlfall.

I am indebted to the editors of *The Journal of Education* for permission to reprint part of an article of mine on "School Accidents : A Legal Survey," to the Methylating Company Limited for permission to reprint the request note on page 125, and to the Worcester Royal Porcelain Company for permission to include their note on Tests for a High-grade Chemical Porcelain on page 135.

I wish to express my great indebtedness to Mr. C. Fox, Principal of the Cambridge University Training College, who first suggested this book, and to Professor J. W. Adamson, Mr. G. H. J. Adlam, and Mr. J. Gray, F.R.C.S., of Guy's Hospital, who kindly read the manuscript and made many suggestions for its improvement.

A. SUTCLIFFE.

CAMBRIDGE, 1929.

FOREWORD

BY CHARLES FOX

DIRECTOR OF TRAINING OF TEACHERS IN THE
UNIVERSITY OF CAMBRIDGE

THE science master at the beginning of his career is faced with a set of practical difficulties which are peculiar to his subject. These difficulties arise from the fact that practical work in the laboratory is an essential part of his teaching work. He has to look after apparatus, materials, chemicals, etc., and not only is he responsible for their upkeep but he has, in most cases, to purchase them or to advise about purchases. The detailed knowledge necessary for these purposes usually takes several years to acquire, is picked up haphazard and frequently at the cost of many failures. The time and effort devoted to these matters is a serious tax on the science master's energy, and anything which tends to alleviate it ought to be warmly welcomed.

For some sessions Mr. Sutcliffe has given a course on Laboratory Instruction to students at the Cambridge University Training College for Schoolmasters, and this book deals with the substance of his course. The lectures have been greatly valued as the students have felt that they were getting information which would guard them from making many mistakes if left to their own devices. But it is not the student

alone who will benefit by the material here presented, since all science masters will find information which is of the greatest practical moment to them. They will learn how to buy their apparatus, and the best method of taking care of it. In the making of solutions and kindred tasks they will learn what to expect from their chemicals in the way of purity and durability! These, and a host of similar essential practical details, Mr. Sutcliffe presents in a convenient form.

A science master nowadays is expected not only to be able to advise on the arrangement of a laboratory but even to make suggestions about planning it. This is as it should be, but it needs adequate preparation on his part. Sound advice on these matters will be found in this book.

In another respect the science master needs help but usually does not get it except in a fortuitous and unsatisfactory manner. He is responsible for seeing that accidents do not occur or for dealing with them when they do happen. He ought to be in a position to deal immediately with any untoward circumstances which may arise and for this purpose the advice given by Mr. Sutcliffe is pertinent, adequate and practical. As far as I know, this information is not to be found elsewhere.

For these reasons I am happy to be able to commend this pioneer book to the attention of all engaged in teaching science in schools, in the hope that it may be as useful to them as it has proved to be to Cambridge University students of Education.

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CHAPTER I

THE LABORATORY AND ITS FITTINGS

THE planning of a laboratory lies within the architect's sphere, and all that a teacher can be expected to know are a few of the general facts and principles involved, with special reference to the management of a class in such a room. With the actual structural arrangements he is little concerned, but he should be able to give advice on any occasion when his opinion is sought. According to the Building Regulations for Secondary Schools, "The provision of rooms for Science teaching should be carefully considered in relation to the work of the school and the number of pupils." Obviously, the Board of Education intend that the architect should consult the teacher, for only the latter is qualified to state the nature of the work of his school. On such occasions, however, the teacher must ponder carefully the advice he gives and see that no particular inclinations and ideas of his own have been stressed unduly. He should remember that the laboratory is to be a permanent fixture of the school, and that he himself will not be the only master who will have to use it.

The number and size of the laboratories are also laid down in the Regulations (paragraphs 50 and 51), thus :

"A school of 150 pupils over 12 years of age will require at least one laboratory, but in a school of this size for boys and girls two laboratories will, as a

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rule, be necessary. A school of 200 pupils or more over 12 years of age will require two full-sized laboratories. In schools of 300 pupils or more three laboratories may be necessary.

"Before the exact dimensions for a laboratory are decided on, the arrangement of benches, fittings, drainage, and flues for fume closets and combustion hoods should be determined and should be shown on the plans, but in no case should there be less than 30 square ft. per pupil.

"It is desirable that the laboratory should be large enough to take a full class, in order to avoid the need for division."

The demonstration bench is the permanent fitting which is used most by the master and is required in every laboratory. Although at least one eminent scientist would dispense with this (see *Scientific Method*, by H. E. Armstrong), it is on the whole desirable to include such a bench. It should be in a suitable position where the master can easily observe the whole of the laboratory with one sweep of his eye, and hence the working benches should be placed parallel to it. For the same reason, most lecture benches are placed on a raised platform some 9 in. high. The step is, however, a disadvantage in some respects, for when a master or his assistant is carrying some delicate piece of apparatus, he has enough to do without having to watch where he treads. A convenient size of bench is 8 ft. long, 2 ft. 6 in. wide, and 3 ft. high. Ample floor space should be provided in front to permit the students to gather round it after some experiments have been performed and to see any apparatus and the like exhibited there. A space of about 5 ft. across is desirable for this purpose. On the teacher's side there should be slightly less distance to provide him with room to move about and work at the blackboard which is placed behind the

bench but is close enough to save any walking backwards and forwards. In some well-planned laboratories this blackboard is a sliding one and opens directly into the store-room placed behind. If this is done and a window-like opening left, with a shelf in place of the window sill, much time is saved in moving apparatus and chemicals from the store-room to the laboratory.

The bench top should be of teak, about 1 to 1½ in. in thickness. It should be provided with a sink of ample size (2 ft. by 1 ft. 6 in.), over which is fitted a movable cover and which can slide and hang down the side of the bench when the sink is in use. If this method is adopted, the water-pipe should be hinged so as to fold into the sink. At least three taps should be provided, one as high as possible, another suitable for a filter-pump attachment, and an ordinary tap. A couple of two-way gas distributors should be placed on the top of the bench near the far edge, and it is often convenient if a piece of asbestos or uralite is sunk into the bench top where any hot piece of apparatus can be placed in a position of safety.

The bench should be fitted with cupboards, preferably with sliding doors to make access easy, and a few drawers. They should be placed on the master's side of the bench. In addition, a waste box for used filter papers, broken glass, etc., is very convenient, especially if made so as to be readily movable for cleaning purposes. The drains connected with this bench should not run under the platform, but should be readily accessible.

In the physical laboratory especially, and possibly in the chemical one, a supply of electricity should be laid on to the demonstration bench. Indeed, in many advanced laboratories, such a supply is laid to every bench and, by a switchboard control, placed near the demonstration bench under the eye of the

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teacher, a supply varying from 6 to 200 volts or so can be obtained. For most elementary work a supply at 6 to 24 volts is sufficient.

It is sometimes advisable to arrange for a screen for lantern work to be placed near this bench, so that it can be lowered over the blackboard. If the lantern is used the laboratory will have to be darkened; although this is possible with safety in the biological laboratory and even in the physical, as a rule it is not advisable to do so in the chemical laboratory, since in the semi-darkness the boys may be tempted to abuse the apparatus and bottles so readily to hand.

The Chemical Laboratory.—The position of this laboratory needs some consideration, for it must be remembered that during the chemistry lessons many obnoxious fumes are produced, and unless the laboratory is in a convenient place, the attendant smell will pervade the whole school. Because of this the chemical laboratory is usually situated on the top floor of the building, and, where possible, is cut off from the rest of the school by a corridor or passage, along which passes a free current of air. Naturally the direction of the corridor should be such that the fumes will be carried away from and not into the school—as occasionally happens.

The minimum space per student is 30 square ft. in all schools receiving grant from the Board of Education; generally, however, this space is far from ample, and even 40 square ft. would be a moderate requirement.

Whenever possible, the working benches should be arranged parallel to the demonstration bench, which is usually situated at one end of the laboratory. If this is done, the teacher is able to supervise the whole of the class more easily than when the benches are placed at right angles to his bench. So far as possible the working benches should not be placed against the

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walls of the room; wall space is required for shelving, ovens, cupboards, etc. A few narrow benches, say 2 ft. wide, could be placed there; these would be useful for holding apparatus in reserve, for apparatus which has to be left overnight, or for distillations and experiments requiring considerable bench room.

The first working bench should be about 5 ft. from the demonstration bench (see above), and the space between each bench such that movement is possible and crowding avoided. This space depends on the type of bench chosen. If the bench is of the single type, *i.e.* where students work on one side only, the gangways should be 3 ft. 6 in. or 3 ft. wide, but in most laboratories economy of space usually demands that the double type of bench be provided. When this is done the gangways should be at least 4 ft. wide. The double bench arrangement, besides resulting in economy of floor space, is cheaper on account of the saving in shelving, woodwork generally, pipes and drainage, and for these reasons is usually preferred in school laboratories. The disadvantage is that the pupils face in two directions; that is, half of them have their backs to the teacher.

The design of the bench is largely a matter of individual opinion. All are agreed, however, that a working space 3 ft. 6 in. to 4 ft. long and 2 ft. 6 in. wide for a single bench, or 4 ft. to 4 ft. 6 in. for a double bench, with a height of 2 ft. 10 in. in each case, is desirable. Also the top should be of 1 in. teak, with the rest of the woodwork in pitch pine or oak. The old type was a long bench, with one or two shelves, to hold the reagent bottles, running the whole length, except for the sinks. The convenience of this is much appreciated by the lazy and mischievous student, who finds the shelving a useful obstruction of the teacher's view. On the other hand, the shelves are a

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useful and convenient place for the storage of the common reagent bottles. When these are provided, they should be fitted in a low position, say 7 in. from the surface of the bench, and they should be 4 in. wide on a single bench, or 8 in. on a double one. In the latter case, the shelf must be divided into two by means of a fillet of wood or in some other manner. The appearance of the laboratory is enhanced if the shelves are laid with white tiles, or pieces of plate glass painted white on their under surface, or white opaque glass. Indeed, in some laboratories the shelves themselves are of $\frac{1}{4}$ -in. plate glass; they slide into slots, or are otherwise supported so as to be readily removable for cleaning purposes.

When the reagent shelves are omitted, as they most certainly may be in elementary laboratories, small movable trays are provided to hold the reagent bottles. Or instead of this, strips of plate glass (4 in. wide by $\frac{1}{4}$ -in. thick for single benches, or 8 in. by $\frac{1}{4}$ -in. for double benches) may be sunk flush with the surface of the bench. This glass may be painted white on the under surface and embedded in putty. Better still, though a little more expensive, sheets of white glass may be used instead.

Cupboards and drawers are usually fitted in the working benches. Drawers are essential; they hold the small articles of common use, pipe-clay triangles, wire gauzes, crucible tongs, etc., as well as the students' notebooks. Alternate drawers may be provided with a small draw-shelf or flap on which the student can rest his notebook when writing his account, so avoiding the use of a dirty or wet bench for this purpose. The dimensions of the drawer are about 1 ft. 6 in. to 1 ft. 8 in. wide, as long as possible from back to front and about 4 in. deep. Thus, allowing 3 ft. 6 in. working space for each student, every place can be fitted with two drawers.

Some suitable device, such as a turn-button, should be fitted on the back of the drawer; this, while preventing the boys from pulling the drawer out completely and perhaps upsetting its contents, enables the drawer to be taken out for cleaning purposes.

Cupboards are not nearly so essential as drawers, but generally, owing to lack of storage room, it is often convenient to fit up the benches with them. Unfortunately, these cupboards are usually damp, especially when the open drainage system is employed. Thus, apparatus of iron—retort stands, tripods, etc.—soon become rusty if kept in such cupboards. It is therefore advisable to back every cupboard, so boarding in the open drain. But to make the drains accessible these backs should be movable; for example, they might be fastened by means of a turn-button. Shelves are required in these cupboards and they are generally fitted round the sides, so leaving the centre of the cupboard high enough to contain a retort stand placed upright. When cupboards are provided ample knee and toe space must be given.

Small waste boxes should be fitted at convenient intervals on every bench, one box for every two places. The waste box holds used filter papers, broken glass, etc. It should be made of teak and lined with pitch, not metal, since some acid may be introduced into the box and would then attack the lining. The box must be arranged so that the assistant can empty its contents quickly and easily.

Every boy should have the use of a sink, although two students on a single bench or four on a double one may share the same sink. The sinks should be about 12 in. by 9 in. by 5½ in. in size and be provided with two taps, at least one of which should be screwed to hold a filter-pump attachment. If the sink is a wooden one, the outlet must be so arranged that there is always some water covering the bottom to prevent

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the wood from warping or cracking. Each sink should empty into a common drain, the exit pipe to be straight and containing no bends. The common drain should empty into a settling trap at the end of the bench before emptying itself into the main drain. This trap keeps back all the accumulation of rubbish which somehow or other always gets into the sink, no matter how careful the teacher or students may be. A plug outlet for the sink is preferable to a number of small holes, since it enables the sink to be used in place of a pneumatic trough, and even in elementary physical chemistry, as a thermostat vessel. A two-way gas distributor should be fitted for each working space.

Every chemical laboratory needs a sufficient number of fume cupboards. In a laboratory for about two dozen students, three such cupboards at least are necessary; four would be more convenient, certainly not an extravagant allowance. They should be situated in convenient places where each student can reach them without having to move too far from his bench. Although fume cupboards are cheap to erect in pairs, this arrangement is not very satisfactory, since it results in crowding. Where space is limited, they may well be built out of the laboratory when what is usually the window serves as the front of the cupboard. This can only be done when the window sill is at a convenient distance from the floor, say about 2 ft. 10 in. Since it usually spoils the appearance of the building, few architects care for this arrangement, which interferes both with lighting and ventilation of the laboratory. It is therefore, perhaps not advisable except in a few instances, such as when one side of the laboratory forms an enclosed space, or where appearances are of little importance.

Each fume cupboard must be provided with

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efficient flue, and a draught may be obtained fitting each flue with an atmospheric burner alternatively, by connecting each to a common and having an electric fan at the outlet of the last. Whenever possible, the flues should be built into walls at the time the laboratory is being erected.

The cupboards are usually about 3 ft. 6 in. long 1 ft. 6 in. to 2 ft. wide, although one of a larger size might be provided. The frames should be of wood (metal frames are attacked by the fumes), and where possible the cupboard should be glazed on the two sides and on the top. A sliding sash is more convenient than a door; it should be arranged to give an opening of about 3 ft. and should be easily movable. Various materials have been suggested for the bed of the cupboard—slate, non-absorbent stone, lead or glazed brick. Of these slate is perhaps the best. Water and gas may be fitted in, if desired, but it is essential that as little metal work as possible be inside the cupboard; hence the water and gas should be regulated from without. If a waste pipe is provided sunk flush with the bed of the cupboard, the latter can be cleaned easily. Finally, lead paint must not be used on the interior walls—it is converted into black lead sulphide by the hydrogen sulphide; instead, a white zinc paint (zinc sulphide is whiter) or a special distemper should be used. Indeed, if it is desired to paint the laboratory, such a paint or distemper should be employed.

The position of the balances depends, as does that of most fittings, on the available space. Special balance rooms are sometimes built, and this arrangement has the advantage that the balances are kept free from the fumes and are usually placed where there is little traffic. For the first of these reasons the balance room should not open directly into the laboratory.

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plan are that a great deal of space is taken up, and that the boys, whilst in the balance room, are away from the supervision of the teacher. The remedy is a suitable arrangement of windows. When the balances are kept in the laboratory, a special bench is often made for them. This bench should be in a place where there is little vibration and where the balances will not be subjected to any great difference of temperature. The shelf should be placed level; it is generally made of slate, although for school purposes a substantial wood shelf would do as well. It should be 1 ft. 6 in. wide and space should be allowed for each student to be seated when using the balance, at least 2 ft. being required. The shelf should be in such a place that the students can work at the balance without being in the way of others passing to and fro. Save in exceptional cases, balances should not be placed on the working benches and, no matter where kept, each one requires a good case, dust- and fume-proof, and with glass sides.

When the positions of the more important fixtures, *i.e.* demonstration bench, working benches, fume cupboards and balances, have been decided, the amount of wall space available for smaller fixtures should be considered. If a separate store-room and preparation room or both combined be provided, the storage arrangements are much simplified, and generally very little else is required in the main laboratory for this purpose. There is no doubt that a separate store-room is a great advantage, and this should be placed as near the demonstration bench as possible (see p. 3). On one side of this room must be placed a number of cupboards, with sliding glass doors and fitted with shelves. Owing to the different sizes of bottles used, these shelves should be movable, although in at least one cupboard the first shelf may be fitted about 2 ft. 6 in. from the bottom. In this cupboard

would be stored such apparatus as the voltameter, the eudiometers, Lunge's apparatus, etc. Shelving should be provided on another side of this room; these shelves may be of various widths, some about 4 in. wide and placed at the top, and a bottom shelf about 1 ft. high and 8 in. wide. On this latter shelf will be placed Winchester bottles containing concentrated acids, etc. In addition to cupboards and shelving, a working bench with cupboards is conveniently placed in the centre of the room, whilst on a small wall bench a large sink, for washing up, is necessary. This sink, 3 ft. by 2 ft. by 1 ft., should be connected with a large grooved draining board which slopes slightly towards the sink. Against the wall should be fixed a vertical board into which inclined pegs are driven. Flasks, etc., can be placed on these to drain. As an alternative, or perhaps additional, a shelf-like structure may be placed over the sink. In it holes, some $1\frac{1}{2}$ in., others 2 in. in diameter, should be bored at convenient distances, so that the flasks may be placed neck downwards in the hole and left there to dry. If hot water is laid in the school, a tap should be fitted over this sink; if not, a small wall geyser, or some other arrangement for yielding a supply of hot water, must be provided. Cold-water taps are of course required, and one of these should be placed about 3 ft. from the bottom of the sink to allow long pieces of apparatus to be readily washed.

If no store-room is provided, arrangements have to be made to store all the apparatus and chemicals in the laboratory. The use of store cupboards in corridors outside the laboratory is to be deprecated, both on account of inconvenience and also because of the risk of pilfering (see p. 138). Cupboards, shelves and sinks similar to those described above will be necessary.

Shelves for reagent bottles are required in the main

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laboratory. These should be fixed so that no boy need move too far from his place ; a suitable position is opposite each gangway. The shelves need to be about 4 in. wide and 7 in. apart, and the highest should not be more than 5 ft. from the floor, so as to be within reach of the boys. About 8 or 9 ft. of shelving is necessary for each set of bottles.

Each laboratory requires a distilling apparatus (which may be placed in the store-room), and drying ovens are essential. Various types of these are on the market ; a combined oven and still is now the most popular model. Obviously, the type to be purchased should be decided first and then the necessary space allowed for it. Sometimes this apparatus can be placed on the side bench, or perhaps a special bench can be made, or, where space is limited, a large stone slab can be let into and supported from the wall. The size of such a slab, etc., varies with the type of still ; but it must be remembered that provision must be made for the vessel which collects the distilled water.

If a muffle furnace is to be used, its position should be decided before building, so that the flue can be built into the wall. In many cases a combustion hood is fitted over one of the benches, and this also requires a flue. Such an arrangement is necessary in an advanced laboratory and is desirable in an elementary one.

The blowpipe table, if required, should be about 2 ft. 10 in. in height and be covered with an asbestos or uralite top. The table should be placed in one corner of the laboratory where it will be free from draughts, and where the light is subdued, for in blowpipe work it is often advantageous to observe the colour of the heated glass, since this is an approximate guide to its temperature. There should be a clear space on the left-hand side of the worker, so

that he can manipulate a long piece of glass tubing in safety.

In addition, the laboratory should contain a long box or a rack to store the glass tubing and rods. A rack is preferable; it should be about 6 ft. long (most of the glass tubing is sold in 5-ft. lengths), and some 4 in. wide. It may be divided into different compartments, somewhat like the rack in a decorator's shop which is used for storing wallpaper, each compartment being 6 in. by 4 in.

A notice board should be placed in a convenient position and a case for the keys belonging to the drawers and cupboards, etc. This case may contain a number of hooks, and each hook should bear a number corresponding with that on some one key. It should be provided with a fume-proof glass front.

It is also advisable to pay special attention to the position of artificial lights. These should be placed so that every working bench is well lighted, as well as the fume cupboards, blackboard and the other large permanent fixtures. Much inconvenience and waste is caused when more than one lamp is connected to the same switch unless the connection has been well planned. Generally speaking, one switch might control all the lights over each bench, another for the demonstration bench and blackboard, and one for each fume cupboard, etc. The casing of these switches should be of gunmetal or phosphor-bronze (as should all the metal work in the laboratory), or, better still, of porcelain. Brass casings are very soon corroded. No light, especially no electric bulb, must be placed immediately above a probable source of heat.

The Physical Laboratory.—This laboratory is most conveniently situated on the ground floor, where there is least vibration; in technical schools and similar buildings, it should not be near the work-

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shop or other rooms containing large masses of iron or electrical apparatus.

The demonstration bench (except for the gas supply), blackboard, balances and the manner of lighting are similar to those described for the chemical laboratory. One fume cupboard at least is required, for work with the Bunsen and Grove cells, etc.

There are two types of working benches in use, fixed and movable. Those of the former type are freer from vibration, whilst when the latter are used free floor space can readily be arranged, as is required for certain experiments, *e.g.* the determination of the magnifying power of a telescope. In most laboratories, however, the benches are fixed to simplify the arrangement of the gas and water supply, and a long bench is fitted running the length of the room, perhaps against the wall, for experiments of the above nature. There is, of course, no reason why a laboratory should not be fitted with both types of bench.

Cupboards are not essential in these benches, but drawers are. All the iron-work should be kept free from the bench top so as to allow a large open space for work. Thus the gas fittings are placed under the edge of the table, which is made to project for this purpose, and oblique holes, 1 in. diameter, are bored near each tap. The gas tubing will then pass through these holes when the gas is in use. All around the table, on the inside of the oblique holes, a groove is made, with an outlet at each corner so that any mercury which is spilt can be collected easily. Above some of the benches may be fixed suspension rails of wood (3 in. by 2 in.), about 3 ft. above the surface of the table. These rails are useful for a number of experiments involving the use of pendulums, pulleys, etc.

Fewer sinks are required than in the chemical

laboratory, and two large sinks are ample for the whole laboratory. One part of the laboratory should be made suitable for work in mechanics. For this, one or two beams can be left exposed, or else a wooden one fixed across the top of this part of the laboratory. Hooks, etc., will be screwed into this by the teacher to support his mechanics apparatus, pulleys, wires, pendulums, etc. The wall in the same part of the laboratory should be boarded to a height of 6 ft. for a similar reason. Such an arrangement may save much plugging of the walls at some future date. In addition, wall-supports for heavy pieces of apparatus, *e.g.* flywheels, and smaller shelves for galvanometers, should be built into the walls.

If no separate dark room is available, all the windows should be fitted with boxed-in dark blinds; whilst if a dark room is made, it should be provided with red as well as ordinary electric lights.

Store cupboards are required either in the laboratory or in a separate room. These cupboards must be quite dust-proof. One should be large enough to hold pieces of apparatus like a Wheatstone's bridge, air pump, etc.; that is, it should be about 4 ft. long by 1 ft. 6 in. wide and 2 ft. 6 in. deep. A number of cupboards about 1 ft. 6 in. back to front, fitted with movable shelves, and a chest of drawers is necessary. Part of this chest may be fitted with very shallow drawers, say 2 in. deep, to hold thermometers, lenses and such small pieces of apparatus.

The Biological Laboratory.—This laboratory should be situated so that it is lighted from the north, for this light, being diffused, is the most suitable for microscopic work. Tables, of a simple design only, are necessary; cupboards and possibly drawers can be dispensed with in these tables. About 3 ft. by 2 ft. 10 in. should be allowed for each working space. Gas should be laid on, but, as in the physical

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laboratory, only a few sinks are required. A place for oven and still should be provided; fume cupboards are not essential. Cupboards, as in the physical laboratory, as well as lockers for the microscopes, are necessary. In addition, there should be a large museum cupboard, two or three large drawers for the herbarium (4 ft. \times 2 ft. 6 in. \times 7 in.) and plenty of shelves for specimen bottles.

The Combined Laboratory.—In many schools one laboratory has to do service for more than one subject, chiefly for physics and chemistry. Usually only work of an elementary nature is done there and the planning may be of a simple kind. Generally, the requirements of physics should take precedence; that is, the benches should be of the type required for work in physics with free bench space. As a compromise, each bench should be fitted with sinks, possibly with movable covers and folding water taps. Cupboards may be fitted to the benches where there is little storage room elsewhere. In place of shelves, small teak trays can be provided for the reagent bottles, and these, when not in use, as during a physics lesson, should be removed and kept on a side shelf near by, or else on one of the shelves in the cupboard. It must be remembered, when planning such a laboratory, that corroding fumes will be produced at times. Hence all cupboards in which delicate apparatus is to be stored should be as airtight as possible, and the laboratory well ventilated.

CHAPTER II

LABORATORY ORGANIZATION AND MANAGEMENT

THE most difficult and trying duty of the science master is that of organizing his laboratory so that work goes on smoothly and efficiently. His tasks are many and range from disciplinary problems to means of ensuring cleanliness; from the ordinary routine work of the ordinary teacher to his own specialized problems. The contents of this chapter seem to fall under the two headings, laboratory discipline and organization, and the care and cleanliness of the laboratory and apparatus. The former will be dealt with first.

Laboratory Discipline and Class Government.

—Freedom is the keynote of modern education, and the strict, mechanical and silent obedience is now, happily, a thing of the past. But in spite of the demands for self-government, the fact remains that discipline is essential; the class must be under the complete control of the teacher no matter by what means this control is exercised. The science master especially must be the supreme authority in his laboratory and must not delegate his powers to anyone. There can be no self-government in a place of such potential dangers, where a moment's disobedience may bring results which last for life. But as strict obedience must be habitual, all instructions given must be carried out to the letter, whether there is any danger or not in a particular experiment,

and disobedience and neglect punished without fail. It follows, as a corollary, that instructions should not be given except when necessary. Too many rules and warnings defeat their own purpose and there is nothing a boy detests so much as "Don't do this, or don't do that." It is better to tell him positively what he has to do and to keep the "Don'ts" until they are necessary.

Yet the science master must not be a martinet. The sign of good discipline is not the silence of apathy, but an atmosphere of healthy work. The laboratory is essentially a workshop, a beehive of industry without too much of the buzz. Some talking is necessary, and it is desirable within limits and at the proper time. Laboratory conditions are directly responsible for this. Few laboratories are large enough to enable every boy to work by himself even if it is desirable in theory, and scarcity of apparatus often prevents it. Hence in most cases the students are paired and with some advantage. Work is done more quickly, and this is an important consideration since the time allotted to science is frequently less than is required owing to the practical nature of the subject. One boy can often help another, especially when a bright experienced boy partners a weak one, though then the willing horse must not, of course, do all the work. A useful arrangement is to make the experienced boy a "demonstrator" (of the university laboratory type); that is, he stands by and sees that the weaker boy does the work correctly. Boys will frequently discuss their work with one another when they would not care to do so in the first case with the teacher. Often, as the result of such a discussion, some important question is raised which ultimately finds its way to the teacher and hence back to the whole class. If the boys work in pairs,

some talking is necessary, but there is no reason why a boy should talk to anyone other than his partner if both know exactly what has to be done. But certain precautions are necessary in this "pair-arrangement." Directions should be given to both and not merely to one of the students. Each boy must know what his partner is doing, and why, for every one must make his own observations, take a note of all the weighings and measurements, write his own account and do this independently. There is not, however, much harm in allowing the students, especially young ones, to check each other's weighings and measurements. In short, the manipulative unit may be the pair, but the mental unit is certainly the individual.

This "pair arrangement" is desirable in the lower forms only, for when a boy reaches the examination form he must work by himself, and in the advanced classes individual work is, of course, essential. But even then some co-operation is at times desirable; for example, during certain experiments in physics, the manipulation is such as requires the co-operation of two students. In chemistry, during organic preparations, when once a student has learnt to fit up apparatus, there is no need for him to spend on every occasion the long time often necessary to do this. In a moderately large class one boy can get the apparatus ready for a particular experiment and then be allowed to demonstrate the experiment to all the boys, with the master standing by, prompting and assisting with questions; or the boy may finish the experiment and then exchange his apparatus, already fitted up, with that of another boy who has done a different experiment.

Although a certain freedom of movement has to be permitted, the laboratory arrangements must be

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such that no boy has to move far from his working bench, and although some talking is allowed, unnecessary noises must not be permitted. Especially when the teacher finds it necessary to address the class must he obtain silence. It is surprising what a good disciplinary influence can be secured in this manner. When a master is going to speak, all bunsen burners must be quietened (but see p. 36), all water taps stopped, every noise subdued. The master should not interrupt too much when once practical work has commenced, and in a well-planned lesson almost the only legitimate occasion for interruption occurs when he sees some general fault in manipulation which has to be corrected at once.

The laboratory is the Happy Hunting Ground of the mischievous boy. What opportunities are presented to him! There is the wash bottle and pipette for squirting, rubber tubing for flicking his neighbour, metre rulers for fighting, lead shot for pea-shooters, mercury for table billiards, the booby trap of emptying bottles and refilling them with water or some other liquid, and so forth. Hence the master has to keep an eye open, for though his sympathies may be with the boy (and even his admiration for some ingenious contraption), he cannot permit such proceedings. It is well to nip such happenings in the bud, possibly by spending the first few lessons in work simple enough to keep the class busy until the master establishes a routine of good discipline.

Economy in the Laboratory.—Science is the most costly of all school subjects, and if the master in charge does not economize as much as possible he may often find himself unable to purchase many necessary things.

The best economy is effected by ensuring that

apparatus is not ruined through ignorance or carelessness. Batteries can be spoilt through short circuiting; resistance boxes and ammeters burnt out by too large a current; thermometers broken through unequal or rapid heating. Hence, before any student is allowed to use delicate apparatus, he must know what it is capable of standing, its sensitiveness to physical changes, and so on. One rule, to which there are few exceptions, must be enforced rigidly—no experiment must be commenced without the teacher's permission. The student may get everything ready to begin, and in experiments in electricity make all the connections; but before the current is switched on the teacher must inspect the apparatus. Any apparatus requiring special care must be marked accordingly.

Renewal of glassware is a costly process, and one way of avoiding this is to purchase only good glassware (see p. 127). When such is used breakages are almost always caused by carelessness, which must be systematically punished, possibly by demanding part payment. In non-rate-aided schools, this is perhaps the best method; but in schools under Local Education Authorities it is advisable for the science master to obtain first of all the permission of the Headmaster. It is not, of course, necessary to make the student pay the full price of a broken article. Indeed, a nominal charge, such as a boy can pay out of his own pocket-money, is better; otherwise it is often the parent who suffers. Money received from breakages may form the nucleus of a petty cash account.

Many a fortune, it is said, has been made out of the halfpence; certainly much money is wasted in small ways. Test-tubes, for example, are thrown away when the bottom has been broken, and yet almost any boy can draw out the tube and seal it up again.

Microscope slides and cover slips are frequently crushed and thrown away when a little care will prevent their destruction. Rubber tubing is treated as worthless and pocketed by many a boy. Filter papers are bought only for filtering, and should not be used for other purposes—they are certainly not the school supply of blotting paper! They should not be used for fetching supplies of solids, for any waste paper can be utilized for such a purpose. Hence in every laboratory there should be pieces of paper, torn into a convenient size and hung in a suitable place. Indeed, writing paper, being glazed, is better than filter paper for this purpose, provided it is clean.

Gas costs money; there is not a free and unlimited supply, even if it appears so to the pupils. Let them recall what their parents would say if a gas light were left on when not necessary. Yet a bunsen burner consumes more gas than many a house light does. All too often one sees bunsen burners lit when they are not required; often they are roaring away when only a small flame is needed; on some occasions they are left alight in an empty laboratory. It is much the same with the water supply; water from the mains has to be paid for by somebody, and waste should be deprecated. Particular care must be exercised in the use of distilled water. The retail price is somewhere in the neighbourhood of 7d. a gallon, and, although most masters make their own supply, the cost of doing this is quite appreciable. The distilled water placed in the wash bottles is not there for washing purposes. Except in the case of advanced students doing work of an accurate nature, tap water is good enough for such operations as the rinsing out of vessels. There are really few occasions during elementary work when ordinary tap water will not serve in

place of distilled. The inaccuracy introduced by its use is by no means of the same order as that due to errors in weighing and measuring. There are, however, localities in which the use of tap water is not advisable, owing to the dissolved matter it contains. Its use must be largely at the discretion of the science master, who should know the nature of the main supply.

Economy can also be effected in the chemical laboratory in the amounts of reagents used. If the Twice Normal System is used (see p. 52), it is an easy matter to make a rough calculation how much to use, and the students, especially in the advanced classes, should be instructed on this point.

Finally, a talk on the prices of the various chemicals and apparatus can be introduced on any appropriate occasion. Few boys realize the price of a good beaker; fewer still know the difference in price between potassium iodide and potassium nitrate, or mercuric chloride and sodium chloride. It may be advisable to mark the bottles containing expensive chemicals. ✓

The Recovery of Substances.—Possibly many substances are not worth the recovery financially. But the difference between a school and a works laboratory is obvious. For when a chemist is paid a high salary it is false economy for him to spend time in recovering certain substances. In a school laboratory, however, the time factor does not enter to the same extent, and the chief consideration is the relative cost of the substances used in the process. Against this latter item must be set the consideration that many processes of recovery make a useful exercise and seem real to the student. A boy, for example, often thinks he is playing at school when told to dissolve a substance in water and then recover it by crystallization. He views differently an

operation such as recovering zinc sulphate from the residues in the hydrogen bottles, or the calcium chloride formed during the preparation of carbon dioxide. Such residues may be preserved and treated as suggested above.

A few definite processes of recovery may now be mentioned.

Silver Residues.—Whenever silver salts are being used, *e.g.* in volumetric work, the solutions and residues left should be placed in a large beaker instead of being poured down the sink. The silver is usually present as the chloride; if not, it must be converted into it by the addition of hydrochloric acid. (It is always advisable to add a few drops of hydrochloric acid to the residues from titrations to ensure that all the silver is present as the chloride.) The precipitate is allowed to settle and from time to time the clear liquid is decanted off until enough chloride to make recovery worth while has been collected. It is then well washed with boiling water and filtered at the pump.

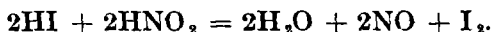
The amount of precipitate present should be ascertained by a rough weighing. It is then transferred to a large evaporating basin and a concentrated solution of caustic soda added. To this, commercial glucose (about four times the weight of the chloride) is added and the whole digested for a few hours until a sample of the residue completely dissolves in nitric acid. This residue is grey silver. It is filtered off, dried, mixed with solid sodium carbonate and a little borax, and then heated in an earthenware crucible over the blowpipe. The silver collects as a metallic mass. This silver may be dissolved in nitric acid to give a solution of silver nitrate, and this, when standardized against a known sodium chloride solution, may be used for volumetric work.

Instead of treating the chloride with caustic soda and glucose as above, it may be reduced in a stream

of hydrogen, or coal-gas, and then fused with sodium carbonate, etc.

Iodine.—It is doubtful whether the recovery of iodine is worth while financially, but as the following process may be used for purifying an impure sample, details will be given.

To the iodine residues (potassium iodide, etc.) is added a solution of sodium nitrite and then one of sulphuric acid. Hydriodic and nitrous acids are formed and these react, forming iodine.



The iodine is filtered off, placed in a large flask and steam distilled. Iodine vapour is insoluble in water and hence the substance settles in the receiver. It is filtered and resublimed.

Mercury.—Mercury readily amalgamates with zinc, lead, copper and many other metals. It must, therefore, be kept out of contact with them. As soon as the mercury leaves a "tail," *i.e.* when it leaves a deposit when run over a sheet of paper, it should be purified. The best method of doing this is by distillation *in vacuo*, but this is a very laborious process and is, generally speaking, unnecessary in a school laboratory. Any of the following methods is satisfactory.

The mercury may be boiled with a very dilute solution of nitric acid, less than normal strength, and then thoroughly washed by a constant shaking with distilled water. It is then dried (using filter paper) and filtered through a paper containing small holes made by a pin, in the apex of the funnel part. It is finally squeezed through the pores of a chamois leather.

An alternative method gives equally good results. The apparatus consists of a long glass tube, about a metre in length, at the bottom of which has been

sealed a piece of capillary tubing. The latter is bent as shown so that the top of it comes above the bottom of the long tube. This acts as a siphon through which the mercury flows into a thick walled collecting vessel.

The capillary tube is filled with mercury and the long tube with dilute nitric acid of approximately $1\frac{1}{2}$ normal strength. The stem of the funnel has been bent at an angle of 120 degrees and has been drawn out to a thin jet.



Impure mercury is placed in the funnel, and on coming out drop by drop, hits against one side of the tube and is deflected to the other. It is deflected in this manner all the way down the tube, thereby falling in a zigzag manner and so coming in contact with more acid. The first lot of mercury which comes out of the capillary tube is the impure mercury first added and should be put through the apparatus again. The mercury is dried as above.

Another method is to place the mercury in a bottle, cover it with concentrated sulphuric acid and draw a current of air through it by the filter pump for a day or so. The current of air stirs up the mixture. The acid is then poured off and the mercury washed quickly with water. It is then dried as described above.

Alcohol and Benzene Residues.—In laboratories where these substances are used in large amounts (*e.g.* where many experiments in physical and organic chemistry are done), these residues are worth the saving. The liquids are recovered by fractional distillation.

The Arrangement of Experiments.—Students in elementary classes all work at the same speed and do the same experiments. This is convenient to the master and usually there is sufficient apparatus to allow this plan to be adopted. In the advanced

classes, however, it is sometimes advisable to allow the student to proceed at his own pace, especially during the physics lessons, for there is usually only one or two pieces of the same apparatus. In such a case the master must have some convenient system whereby he can readily learn what the student has done and what he is doing. The following plan has been equally successful both in the chemical and physical laboratories. In the former the students prepare their own stock of volumetric reagents.

A large sheet of paper or cardboard is ruled vertically and horizontally. At the end of the horizontal columns are written the names of the experiments, arranged approximately in the same order in which they will be performed, similar experiments being placed together.

The names of the students are written at the top of the vertical columns. The horizontal columns may be divided into sections; for example, in chemistry one section will be reserved for volumetric work and will have sub-headings as acidimetry and alkalimetry, silver nitrate, potassium permanganate and iodine titrations. Each sub-division is further divided so that one experiment is at the head of each vertical column. Other sections will be reserved for gravimetric analysis, experiments in physical chemistry, organic and inorganic preparations. A very useful section, where much qualitative analysis is performed, is one merely numbered consecutively. These numbers correspond to numbers on the labels of bottles containing different mixtures specially prepared for analysis. Hence the students may work at their own speed when doing this type of work.

When a particular student has been allotted an experiment, a diagonal mark is made in the appropriate column. When the experiment has been finished, written up, and the account initialled by

the master, but not before, a cross is made in the column, so indicating that that particular experiment has been concluded. The master should inspect this chart occasionally, and is then in a position to stimulate the slacker or advise the student who has been absent what to do (see Appendix III).

The Laboratory Log Book.—A very convenient book in the laboratory is one in which miscellaneous details can be entered and so preserved. In that belonging to the chemical laboratory there would be entered the composition of the mixtures made for analysis, the melting- and boiling-points of the organic substances usually prepared, and various data relating to experiments in physical chemistry, *e.g.* partition co-efficients, the solubility of different substances, etc.

The value of such a book is more apparent in the physics laboratory, entries being made of the focal lengths of the mirrors and lenses likely to be used, the water equivalents of the various calorimeters, the galvanometer constants, the E.M.F.'s of the different cells, and so on. Each piece of apparatus likely to require registration in this manner will be appropriately numbered. (Duro ink may be used for the glass, or the latter may be etched.) Reference should then be made easy.

The Stock Book.—Part of the duty of the laboratory assistant is the keeping of a stock book. This should contain a list of all the apparatus in the laboratory, with the number of each piece that the master considers necessary for the efficient working of his laboratory. The assistant will revise the book periodically and enter in the proper column the number of each article in stock. This book should be presented to the master, who will inspect and initial it, and so see what stock requires renewing. Any purchases made will be entered, with the date

of purchase. Such a book is useful when any new brand of glassware, for example, is purchased, for then a rough comparison between the various grades can readily be made.

The Care and Cleanliness of Apparatus.

In this section the names of the various topics mentioned will be arranged in alphabetical order. Attention may be drawn also to the chapters on Chemical Reagents, The Physical Laboratory, and Biological Apparatus and Material.

Balances.—The location of the balances is usually out of the control of the teacher. His duty lies as far as is possible, in preventing corrosion due to fumes and spilt chemicals, and in ensuring that the balance is treated with due care. Balances should be kept in cases, and, especially in the chemical laboratory, should not be removed from them when weighing. If it is necessary to take the balance elsewhere, it is advisable to remove the pans and supports so as to avoid any jar which may ruin the knife-edge.

The atmosphere inside the balance cases of delicate balances, and those with steel knife-edges, should be kept dry. For this purpose a small vessel containing quicklime should be placed within the case. All weighing must be done on watch-glasses or in a weighing bottle. Volatile and deliquescent substances should always be weighed in a closed vessel; chemicals should on no account be allowed to come in contact with any part of the metal, especially the pans.

Unless care is exercised, weights, especially the fractional ones, are soon lost. Hence a monitor for each class may be appointed, whose duty is to go round at the end of each lesson and check the weights. It is very helpful to keep the small weights on a plate fastened to the wooden base of the balance. These weights should, if possible, be covered by a

glass slide. The plate is divided into an appropriate number of spaces, each space indicating the place for the corresponding weight. Such plates, ready marked, may be purchased from most laboratory outfitters.

Balance pans, no matter how carefully used, in time get dirty, and although this can be avoided partly by placing counterpoised filter papers on each pan, the master has ultimately to decide whether or not he will clean the pans. The obvious disadvantage of cleaning such pans is that the adjustment of the balance is destroyed. But some readjustment is rendered necessary owing to the state of the pans.

The cleansing is an easy matter: if the pans are at all greasy, they should be dipped for a moment in a very weak solution of ammonia, washed with water and then polished with any non-gritty metal polish. When the pan is very dirty, it may be necessary to dip it in a dilute solution of nitric acid. In this process an appreciable amount of metal may be dissolved, and hence it should be used on few occasions. Either process destroys the covering of lacquer; hence it is necessary to apply a new coating. The balance must then be readjusted. During this cleansing process care must be exercised that the delicate parts of the balance, the knife-edges, etc., do not come in contact with acid.

A few of the laboratory outfitters will recondition balances, and a really old decrepit balance can be made as new for 16s. to £1.

The Barometer.—Every school laboratory should possess a Fortin's barometer, or some such reliable instrument. This should be hung in a vertical position from the top hook so that its central line coincides with the string of a plumb bob. The bottom attachment must then be screwed fast. The barometer should be placed in a well-lighted position,

with the scale about 5 ft. from the ground so as to be readily readable. It must not be placed near a radiator, or in any place where the temperature is liable to fluctuate. When once fixed in position it requires little attention.

If it is ever necessary to remove the barometer to a new position, the screw at the bottom should be adjusted so that the barometric tube is full of mercury. This is done in case the barometer is accidentally shaken during transit, when the mercury will not bump against the glass and cause a breakage. It also prevents the air from entering.

The Bench Tops.—In old laboratories the bench tops were usually made of yellow pine or red deal, but these woods are not waterproof, since they contain little or no natural oils. Hence bench tops of such woods have to be made impervious to water and other liquids, or else the wood will rot. One method of doing this is to apply a thin coat of paraffin wax. This used to be done by means of hot irons, a piece of wax being put on the bench and then ironed in. Instead of doing this, the wax may be dissolved in petrol (1 part of wax to 5 of petrol) and the solution applied with a cloth or brush. Benzene or xylol may be used instead of the petrol. Some of the wax soaks into the pores of the wood; some forms a thin film on the surface.

The chief advantage of using paraffin wax is that it is impervious to water, weak acids and alkalis. It is not, however, impervious to concentrated acids or alkalis, and must be renewed periodically. Moreover, in time the surface presents a dirty and often untidy appearance, for, owing to the heat reflected from the bottoms of vessels, sand trays, etc., the wax "sweats," that is, it melts in the neighbourhood of the heat supply. This results in an unequal distribution of the wax; and if any substances are

spilt while the wax is still molten, they are retained and create a dirty appearance on solidification of the wax.

Modern bench tops are made of teak, a wood of great density and small porosity and one which contains much natural oil. It is therefore almost impervious to water without any treatment, but its "life" can be lengthened and its appearance enhanced by a periodic treatment with a mixture of linseed oil and turpentine, in equal proportions by volume. The mixture must be rubbed well in; otherwise it leaves a sticky surface for some time. Some people prefer an ordinary floor polish, and this seems to answer satisfactorily.

Pine or deal tops can be treated in a similar manner and if the wood appears too light in colour, it can be darkened by the use of a dark water stain, applied before the linseed oil mixture. Better still, vandyke brown with a trace of dragon's blood powder, dissolved in turpentine, or in the linseed oil and turpentine mixture, may be used. Afterwards the top may be treated with a thick solution of vaseline dissolved in benzene, or, as before, with the linseed oil. In each case the covering mixture must be rubbed well in: in this rubbing lies the secret of a good hard surface.

The Bottles.—The number of bottles used even in a small laboratory is considerable. For example, on each working bench there are at least a dozen reagent bottles, and if the numbers on the side shelves and in the store-room are added to the former, the total soon reaches into the hundreds. These may be of all shapes and sizes, and usually there is little attempt made to secure any uniformity.

Bench reagent bottles should be round, narrow-mouthed and have a flat round-headed stopper; the stopper can then be laid upside-down on the bench without fear of introducing a foreign sub-

stance into the bottle. These bottles should hold approximately 250 c.c., except those for the rarely used substances, *e.g.* silver nitrate, cobalt nitrate, ferric chloride, when a bottle of 75 c.c. capacity is large enough. For the side-shelf reagents a larger bottle of 500 c.c. capacity may be used. All these bottles, large or small, should be of the same type. The store bottles which are supplied by the vendors are of various sizes, depending somewhat on the substance they contain. When a new laboratory is being fitted out, or at other times, uniformity can be attained by requesting the vendor to supply the chemicals in one type of bottle only. Even then some bottles will be small, some large, and there seems to be no simple method of avoiding this.

When supplies are being renewed, since each bottle is charged for, sometimes at a ridiculous price, either the old bottles should be returned and credit claimed for them, or else the order form should state that bottles are not required, except where necessary.

The methods of labelling these bottles are many ; at one time the label was sand-blasted on the bottle, or else put on in enamel. Such permanently worded bottles are naturally more expensive than plain ones and their advantages are obvious. But some specimens are not readily legible, especially when full of solution. There is also the difficulty of replacement, which is overcome by carrying a bigger store than is convenient, for each bottle can only be used for the substance for which it is labelled. Hence many prefer to use such bottles only for the concentrated acids and alkalis, and perhaps for dilute solutions of these, and to use a plain bottle with a paper label for the other solutions.

Printed labels can be bought, and naturally these look much neater than written ones. At times the latter have to be used, and in such a case the writing,

if done in Indian ink, both keeps longer and presents a better appearance. Paper is of course attacked and often destroyed by many of the solutions, and must therefore be protected. This may be done by giving the label a coating of paraffin wax. Before this is applied the label should be securely affixed, especially at the corners. It should not be necessary to state that the label should be cut and not torn from the book, and made as neat as possible before applying. The paraffin wax should be heated and applied quickly and evenly with a brush. A narrow margin of wax should be left around the label, which, when dry, is cut neatly and squarely round and the spare wax scraped away. Waxing a label is not as easy as it reads. Usually the chief cause of failure lies in the wax being either too hot or too cold. It should be heated until it just begins to smoke and applied immediately. Unless the paper is sized, the wax sinks into the pores and so makes the paper semi-opaque, thus decreasing the legibility of the writing. Paraffin wax is impervious to all solutions except concentrated acids and alkalies. The labels can be removed easily by scraping.

Instead of wax a paper varnish can be used. A suitable one is made by dissolving 20 grams of celluloid (an old photographic film will do when freed from gelatine, etc.) in 300 c.c. of amyl acetate, or acetone, or a mixture of both in equal proportions. It can be applied in the cold, and since it leaves the paper unaltered, no size is required. Labels so treated can be removed by scraping.

Before labelling any bottle the old label must be removed. Nothing looks so unseemly as a number of old labels on one bottle and, more important still, there is a real danger that the new label may become detached and the contents of the bottle misused (see Shelves, p. 45).

"Bumping."—Many liquids can be heated above their normal boiling-point without boiling resulting for a time, but, when boiling does commence, it does so violently with the rapid evolution of much vapour. This causes "bumping"; that is, the vessel and its contents are agitated in a violent manner and occasionally the vessel is thrown off its support.

The remedy is to ensure a steady evolution of vapour, and this is done by introducing a nucleus around which a large bubble may form. Porous substances are usually employed since the pores contain air which acts as the nucleus. Suitable substances are pieces of porous pot or earthenware, charcoal, or glass capillaries sealed at one end or in the middle. Obviously the solid introduced must have no chemical reaction with the liquid which is being heated. It should be added when the liquid is cold; otherwise there is considerable danger, since vapour would be evolved rapidly.

The Bunsen Flame.—The flame emitted by a bunsen burner may, for descriptive purposes, be divided into three parts: an innermost cone of no combustion (the cold part), a central portion where there is partial combustion, and the outer part where combustion is complete. The latter is the hottest portion and is the oxidizing flame, since there is no unburnt carbon left. The middle part contains unburnt gases, which require oxygen for their complete combustion and is therefore a reducing flame. Accordingly, when the borax bead tests have to be performed in the oxidizing flame, the platinum wire should be put in the outer cone of the flame, and when in the reducing flame, in the middle cone.

Both reducing and oxidizing flames are required in blowpipe analysis. If the blowpipe is put near, *but not in* the flame, the latter is diverted horizontally.

The region of partial combustion is then half-way between the non-combusted part and the outer tip, and the substance to be reduced should be placed there. When an oxidizing flame is required, the blowpipe is put *into* the flame and air is then blown into it, thus promoting more complete combustion. The substance to be heated is placed at the tip of the outer flame.

The air and gas supplies should be regulated so that the bunsen burns quietly; a bunsen does not give out more heat because it roars. A study of the structure of the flame also shows that it is useless holding a bunsen flame near the vessel to be heated, for this brings the cold region of the flame (*i.e.* the portion of unburnt gases) into contact with the bottom of the vessel.

The Cleaning of Apparatus (General Remarks).—Part of the student's training is one in cleanliness, and dirty, untidy work should not be permitted. The bench tops must be kept as free from apparatus, etc., as possible. Thus bottles should be replaced immediately after use, apparatus finished with removed, and so forth. When there is a laboratory assistant his duty is not, primarily, to clean apparatus for lazy students, although often he has to give some assistance, owing to lack of time and other considerations. Usually it is a very simple task to clean a vessel immediately after use; water and a brush are all that are required (test-tube brushes and burette brushes should be placed in convenient places). But when the chemical or dirt has been allowed to dry and set hard, its removal is often a matter of considerable difficulty.

The simplest, yet very efficacious, method when washing a large quantity of bottles, flasks, etc., is to place them in a bucket of cold water in which washing soda or soap has been dissolved. The water

is then heated very gradually until the assistant is just able to place his hand in the hot water. (This heating is best done over a ring burner such as is employed for domestic use; but when such is not available, a simple stand may be made by using a few bricks and resting the bucket on this. Most tripod stands are too flimsy to stand the weight of a bucket of water.) Each article is removed separately, rinsed out with cold water and then dipped in a weak hydrochloric acid solution, to remove the alkali, and washed with water again. It is finally placed upside-down in the draining rack.

For very dirty vessels one of the following methods may be employed. The outside may be cleaned by scrubbing it with a brush dipped in caustic soda, or more simply by rubbing sand over the vessel with the hand, all the time allowing a stream of water, preferably warm water from the geyser, to run over it. Since sand cuts the glass a little, wood ashes or charcoal may be substituted in its place.

The inside of the vessel may be cleaned by the use of some particular liquid, *e.g.* nitric acid, hydrochloric acid, caustic soda, chromic acid or aqua regia. Which liquid is used depends upon what the vessel originally contained. Along with this solvent, sand, or wood ashes, is introduced into the vessel, which is then shaken. (Glass beads or lead shot make a useful alternative, though when lead is used it is necessary to follow it with a thorough washing with nitric acid.) Finally, the vessel is rinsed out with water and left upside-down to dry.

If the dirt cannot be removed by one of the above methods, "ballooning," as it has become termed, may be tried. About 20 c.c. of concentrated nitric acid are introduced into the vessel and afterwards 5 c.c. of alcohol are added. These two react violently, with the evolution of much heat, and the hot liquid

removes most substances. But certain precautions are very necessary. The action of nitric acid on alcohol is a delayed one, but when it starts it does so very suddenly and with violence. So much so that the fumes of nitrogen peroxide produced are shot out of the top of the vessel with great force. Hence the operator must stand away from the vessel. Moreover, since the nitrous fumes produced are poisonous and have a delayed action on man (see p. 151), the operation must be performed in the fume cupboard. After such a treatment the vessel needs rinsing out with water as above. Obviously the simplest method should be tried first and "ballooning" should be resorted to only on rare occasions.

The foregoing applies to vessels in general, but often it is necessary to have a vessel *chemically* clean before proceeding to an experiment of a delicate nature. For this purpose a chromic acid solution is invariably used. This is prepared by dissolving 10 grams of chromic acid in 100 c.c. of water, or 10 grams of potassium bichromate in 100 c.c. of water to which 10 c.c. of concentrated sulphuric acid have been added. The vessel is washed out with this solution, or better still, the solution is allowed to remain for some time in the vessel, which is finally rinsed out with distilled water. A pull-through, such as is used for cleaning rifles, may be improvised and used for such long pieces of apparatus as the condenser. The chromic acid solution can be used several times and should therefore be preserved for future use.

After the final rinsing with water, the vessel should be left to dry either in the draining rack or in a special drying cupboard. The surface is left in a better condition if the vessel is dried in a current of cold dry air, for warm air usually leaves a stain. If the vessel is to be dried for immediate use, it should be rinsed out with alcohol (or ether) and a

current of hot air forced into it. To do the latter the vessel may be warmed and a current of cold air forced in by the bellows. It is more usual to use for this purpose a piece of resistance glass tubing, connected with the bellows and heated in one part (iron or copper tubes have also been recommended for use). The tube leads into the vessel to be dried and the warm air forces out the alcohol vapour.

Other remarks on the cleaning of apparatus appear under the headings of the articles concerned.

Cleaning the Hands, etc.—The chemistry master usually carries the sign of his profession about with him in the form of stained fingers and acid-pitted clothes. Some of the stains are, however, removable if attended to at once. The most common ones are those produced by nitric acid and silver nitrate.

The former are removed to some extent by the immediate application of a solution of potassium permanganate, which is allowed to remain on the stain for a few minutes. It is then washed off with a weak solution of hydrochloric acid, after which the hands should be washed with soap.

Silver nitrate stains can be removed by the application of a solution of potassium cyanide or potassium iodide, followed by water. Old stains should be treated with concentrated acetic acid before the above process is carried out.

Acid on the clothes should be neutralized immediately with ammonium hydroxide and strong alkalies by acetic acid, followed in both cases with water.

Any concentrated sulphuric acid spilt on the bench or floor should be washed away with copious streams of water, or if this is impossible, chalk or some similar substance should be added at once; otherwise the acid will eat away the wood.

Corks.—Two varieties should be purchased—a very good grade of natural cork and a cheap variety.

The latter is a "composition" and is made of small pieces of cork cemented together and moulded into shape. Such corks are serviceable as simple stoppers, but cannot be bored. Bark corks are porous and hence should not be used in vessels containing volatile substances. They may, however, be rendered air-tight by immersing them in molten wax for five minutes, or by soaking them in a solution of vaseline in benzene.

When boring a cork great force must not be used, but the borer pressed lightly as it turns on its own axis. A cork is bored half-way in each direction and care exercised that the borings meet. The hole can be smoothed by the use of a rat-tailed file, and, if not large enough, may be made bigger by a rat-tailed rasp, followed by a suitable file. The cork borers require sharpening at times, either by a special cork-borer sharpener (which can be purchased from any laboratory furnisher), or by means of a file or hone. When the file or hone is used, the borer should be rotated gently and care exercised that the hole is not forced out of shape (see also Rubber Stoppers, p. 48).

Crucibles (see also p. 134).—Crucibles are made of three kinds of material—porcelain, metal or silica. Porcelain crucibles are dealt with on p. 135. Metallic crucibles are made of either platinum or nickel; usually platinum crucibles are too expensive for school laboratories. Metallic crucibles are not liable to fracture by heating and are not fragile. But they must not be used with fusible metals or compounds of metals likely to be reduced at a great heat. Thus substances containing the following should not be heated in metallic crucibles—antimony, arsenic, bismuth, lead, silver, tin or zinc, as well as sulphur, silicon and phosphorus. Neither should certain chlorides (especially lead chloride), caustic

alkalies or their sulphides, nitrates, nitrites and cyanides be heated in these crucibles. Since the metals readily form alloys, the crucibles must never be touched with the tongs when red hot.

Silica crucibles are attacked by the alkalies as well as salts of lead and other metals (see p. 129). They may be used for heating calcium and magnesium compounds and are far superior to metallic ones. The contents of such vessels must be kept continuously neutral.

Dirty crucibles may be cleaned by nitric acid, hydrochloric acid or sulphuric acid. A little of the acid is added, the vessel heated, then allowed to cool and finally rinsed out with water.

Crucible tongs should be preferably of nickel, since this metal is more resistant to acid attack than bronze or brass. Iron tongs are, however, fairly serviceable, but rust readily.

Cupboards and Drawers.—Constant care is necessary if these are to be kept clean and tidy. As far as possible each cupboard and drawer should be allotted to one individual who is responsible for the contents and cleanliness of the cupboard or drawer. A list of what should be contained therein may be posted inside the cupboard, and an inspection made by the master at any spare moment. It is well to avoid holding regular inspections, or the boys will have a "spring cleaning" just before the inspection.

Evaporating Basins.—Much of what has been written about crucibles applies also to evaporating basins. Such vessels are usually glazed and, when this is so, a good specimen should stand the following test. Into the basin place a concentrated solution of ferric chloride or copper sulphate and boil for a considerable time. Pour out the solution and rinse with water; no stain should appear on the sides of the basin.

The safest method to employ when heating an evaporating vessel is to place it on a sand tray. At other times the flame should not be allowed to play on the porcelain at a height above that of the level of the liquid inside. If it does, there is a considerable risk of fracture.

Dirty vessels can be cleaned by means of water and ashes, or by an acid or caustic soda with ashes or sand. It is sometimes necessary to boil the basins in a solution of caustic soda, especially if the outside has become soiled.

Ironwork.—Owing to the action of chemical fumes and water, the ironwork, especially in the chemical laboratory, soon becomes corroded and rusty unless precautions are taken. When choice in the metal can be exercised, gun metal or phosphor bronze is to be preferred for gas and water taps and other permanent fixtures.

Pieces of apparatus such as retort stands, tripods, etc., rust readily, especially when kept in damp places (and many of the bench cupboards are damp). These stands should be painted periodically, but it is quite useless to paint over rust. Paint is used not to cover the rust but to prevent its formation. Therefore the rust must first be removed by some suitable scraper and emery cloth. The article, if small enough, may be dipped in dilute nitric acid or, if this does not remove the rust, in the following liquids. A solution is prepared containing 6 parts by volume of concentrated sulphuric acid, 1 part of hydrochloric acid and 150 parts of water, and the iron immersed and left in it for a day at the least. On its removal the iron is dipped for a minute in a bath containing 1 part of sulphuric acid to 8 of a weak solution of zinc sulphate (25 grams per litre). The iron is then warmed, dried and painted.

Mortars and Pestles.—The science master may

choose between porcelain mortars—glazed or unglazed on the inside—iron or steel mortars, or agate mortars. The glazed porcelain mortars have naturally a good appearance, especially when new; but unless the glaze is of good quality, it is soon worn off during the grinding process. The glaze also permits the substance to slide over it during the grinding, and hence this operation is made more difficult. Unglazed porcelain often retains the colour of many substances, thus giving the mortar a dirty appearance. Glazed mortars should not be porous, and a simple test for this is to place some highly coloured solution in the mortar, *e.g.* a solution of chromic acid, and to leave it there for twenty-four hours. On rinsing the vessel out with water, none of the colouring matter should be retained.

Porcelain mortars are readily cleaned by placing in them sand and nitric acid, sulphuric acid or caustic soda, and grinding the sand round the sides. This is followed by a rinsing out with water. Since such vessels have very thick walls, they must not be subjected to sudden changes of temperature; for example, water and sulphuric acid should not be mixed in such vessels.

Porcelain pestles are usually supplied and used with porcelain mortars. Some of these are two-pieced, a piece of wood being cemented on to a piece of porcelain. Unfortunately, owing to the violent shocks to which they are subjected, the cement often breaks loose, or else, on becoming damp, the wooden handle shrinks and comes apart. For these reasons one-piece pestles are to be preferred.

An iron or steel mortar is of use when such substances as marble or ammonium carbonate have to be broken up, and at least one, a fairly large one, is required in every laboratory.

Agate mortars are much more brittle than the

other kinds, and will not withstand hard blows. During grinding the pestle should be rotated gently, with a slight downward pressure. They have a smooth surface, are not porous and are readily cleaned. Usually they should be used in work of a delicate nature where small quantities of substances are employed. They have, however, a high silica content, and therefore alkaline substances should not be ground in them.

Ovens.—Many laboratories contain a water- as well as a hot-air oven. The advantage of using the former type is that a constant temperature of about 100° C. can easily be maintained. (Although water boils at 100° C., some heat is lost, so that the temperature of the oven is usually a few degrees below this. Hence the thermometer must always be placed inside the oven.) The chief precaution in using a water-oven is to prevent it from boiling dry. A convenient method of doing this is to place a piece of glass tubing in the hole by which the water is introduced. This tube serves as a gauge; thus a sample of the water is extracted from time to time by placing a finger on the top of the tube and withdrawing the latter. The height of the water in the tube is, of course, the height of that in the oven.

A combined oven and still is very economical in gas, since a supply of distilled water can be obtained at all times when the oven is being heated.

Where a temperature higher than that of boiling water is required, a liquid with a higher boiling-point may be used in place of water. But owing to the difficulty of cleaning the oven, many prefer to use the hot-air oven instead. It is an easy matter to regulate the temperature by adjusting the height of the flame; but where it is necessary to maintain a certain temperature for accurate work a thermostat should be used. Obviously the bulb, or other sensi-

tive part of the thermostat, should be placed inside the oven.

Platinum Vessels and Foil.—Platinum vessels can be cleaned by boiling them in concentrated hydrochloric acid. If this has no effect, solid potassium bisulphate is placed in the vessel, which is strongly heated. When the salt has melted, the vessel should be gently moved, so that all its surface comes in contact with the molten bisulphate. Water should then be boiled in the vessel until all traces of the salt have been removed (test the washings with barium chloride).

Platinum foil can be cleaned in a similar manner. If the foil has become creased, it may be smoothed out by placing it on a hard surface, *e.g.* a piece of glass, and passing some hard smooth object, *e.g.* the thumb-nail, over it in a manner similar to that used by boys in smoothing silver paper.

Shelves.—The shelves and their contents require little attention if some such system as the following is adopted. Each shelf and every bottle is labelled with a distinctive number and letter. Thus the reagent shelf on the first working bench is labelled with the letter A, the second with B, and so on. Every bottle on the first shelf is also labelled A and each bottle given a characteristic number, which is retained throughout the laboratory. For example, the sulphuric acid bottles will be labelled A1, B1, C1, the hydrochloric acid bottles A2, B2, C2, the nitric acid bottles A3, B3, C3, and so on. It is then possible to check at a glance which bottle is out of place and to know where it should be. It is also possible to make some boy responsible for each bottle, and possibly he may also be allotted the task of keeping the bottle full, though unless the boys are very reliable, this duty is best performed by the laboratory assistant. It is he who should

fill the bottles containing concentrated acids (see p. 140).

A similar plan can be adopted for the side shelves. In this case it is useful to label the front of the shelf, showing what bottle should be kept above the label. In short, the ideal is to have a place for everything and everything in its place.

Sinks.—Unless careful laboratory habits have been formed, the sinks soon become full of all kinds of rubbish. They should, of course, be kept clean, and the only way of securing this is by a rigid laboratory routine. That is, after each lesson the sinks should be inspected and any offenders dealt with. The cause of most of the trouble is lack of sufficient waste boxes, for then the sinks are used to answer for this purpose.

Concentrated acids, especially hot sulphuric acid, must never be poured into an empty porcelain sink. For the sink is always a little wet, and the heat of solution of the acid in water is sufficient to do damage. Therefore water must always be added to the sink first and the acid poured into this a little at a time.

Notwithstanding all the care taken, the sides of the sinks get dirty owing to the nature of the precipitates and solutions poured into them, and it will be necessary to clean them at times. This can be done by rubbing the sides with a paste of sodium bisulphate and water, or of washing soda, or soap, or simply by using fine sand and water. If desired, the sinks may be freshened by an occasional sprinkling of bleaching powder. It is not necessary to add water; merely scatter the powder over the sides of the sink and leave overnight. Incidentally, this also disinfects the drains, which is at times desirable.

The traps and the drains should be cleaned out periodically to prevent local flooding, for it is sur-

prising what substances find their way into these places.

Stoppers.—*Methods of Loosening Fixed Ones.*—

When a glass stopper becomes fixed it must not be forced free, but one of the following methods employed. The stopper should be tapped obliquely with a piece of wood, this in itself is often sufficient. If this is not successful, the outer neck of the bottle should be heated over a small luminous flame, all the time rotating the bottle. This causes the glass of the neck to expand a little, while the stopper itself, not being heated, does not expand and so can be withdrawn. Obviously, since the success of this method depends on the fact that the outer glass alone is heated, the heating should be done quickly. This method, however, is not advisable when the vessel is valuable, or if the glass is very thick, since there is considerable risk.

A safe method is to add a drop of oil or glycerine round the stopper and allow it to remain there for many hours until it has percolated through. The oil can be made less viscous by heating it gently. Other liquids may be used in place of oil and should be used when the nature of the cementing substance is known. For example, if the stopper is known to be cemented fast by sodium carbonate, hydrochloric acid will be used.

Care beforehand will often prevent the nuisance of a fixed stopper arising, *e.g.* rubber stoppers should be used where there is a possibility of a cementing substance being formed (*e.g.* in bottles containing sodium hydroxide). Before any apparatus is put away, the stopper should be washed and regreased if necessary. This applies especially to the taps of the burettes which have contained alkaline solutions.

Stoppers, Rubber.—Rubber stoppers are sold bored or unbored, but for most purposes it will be

found that stoppers purchased ready bored are unsuitable, for the holes are usually much too small and are bored in the centre of the stopper; hence it is a difficult matter to bore another hole in such a stopper as is often required. It is therefore better to purchase the unbored variety.

Boring a hole through a rubber stopper requires more care and is more difficult than boring one through a bark cork. To attempt this without first sharpening the borer usually results in failure. The rubber grips the borer and great force is necessary unless the friction between the borer and rubber is diminished. When this is done, boring is quite simple and therefore the borer should be dipped in vaseline and care taken that the vaseline enters the aperture by withdrawing the borer and redipping. Glycerine, oil, or caustic soda may be used instead of the vaseline.

Glass tubes, thermometers, etc., which have stuck fast in the hole can be loosened without applying great force. The rubber should be pressed away from the glass with the finger, little by little, and water added in the opening so formed. This is repeated until the tube slips through easily. When the glass is known to be cemented fast by a certain substance, an appropriate solvent will be used in place of the water.

Rubber is readily moulded, especially when hot, so that a rubber stopper should not be left in the neck of a hot vessel, since the glass, on contraction, will mould the rubber into the shape of the opening, and the stopper will be spoilt for many purposes.

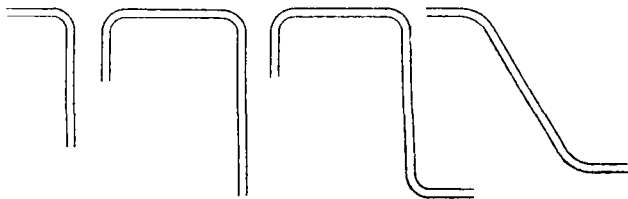
The Storage of Apparatus.—A well-planned system of storage, especially when the laboratory accommodation is limited, is a most valuable factor in promoting the efficiency of the laboratory, and again the ideal is to have a place for everything and everything in its place.

Every similar piece of apparatus should be stored in the same place, *i.e.* all the beakers together and so on. A list of all the apparatus and the place of storage should be posted in a convenient place, and for this reason every cupboard should be labelled with a distinctive number or letter.

In the physical laboratory many pieces of apparatus can be left fitted up on the bench where they will be used, but, where the laboratory is used for chemistry as well, this plan cannot be adopted, since the fumes produced would probably ruin the apparatus. Hence it is necessary to make the cupboards in such laboratories as air-tight as possible.

In a similar way, many pieces of apparatus may be left fitted up in the chemical laboratory, *e.g.* the hydrogen bottles with their thistle funnels and delivery tubes (similar bottles serve for the preparation of carbon dioxide), drying bottles full of concentrated sulphuric acid, and U-tubes containing calcium chloride. Flasks may be left fitted with rubber stoppers (but see p. 48), and siphon bottles may be left ready for the determination of the hydrogen equivalent of a metal.

Sets of different types of delivery tubes should be made; the useful types are shown below.



Combined burette and pipette stands can be purchased from most of the dealers, or the old type can be converted by placing two cross-pieces on the stand and boring holes in them for the pipettes.

For advanced work in chemistry, it is often convenient to provide the students with a set of apparatus, see Appendix II. Many schools cannot afford to supply every student of the elementary classes with a set of apparatus, and such a plan is not necessary. Beakers, flasks, and the like can be stored on separate trays and the assistant will bring out the full tray when required. An inspection of the tray at the end of the lesson will ensure that the vessels are put away clean and that none have been broken or cracked without the fact being reported.

(For remarks on the storage of chemicals see Chapter III; the storage of physical apparatus and of biological apparatus is dealt with in Chapters IV and V respectively.)

Thermometers.—The type of thermometer in general use in school laboratories is that reading to 100° C. and 232° F. with a moderate degree of accuracy. In addition, at least one set of thermometers, of an accurate nature, reading in one-tenth of a degree Centigrade, as well as a few reading in degrees to about 400° C., are required. On some of the common thermometers the graduations are marked on the stem. Others consist of two parts, the thermometer bulb and stem and a scale of paper, "milk glass," wood or ivory substitute. The scale in some types of the latter thermometers is attached to the stem by wire or some such manner, and often slips loose, thereby registering a wrong temperature. Occasionally the material of which the scale is made shrinks, producing a similar result. These thermometers are, moreover, very bulky and oval in section. Thus they are not suitable for many purposes, *e.g.* they cannot readily be passed through a hole in a cork and are often too large to go through the neck of many vessels. The best type of ther-

mometer is one with the graduations marked on a thin cylindrical stem and which possesses a long and narrow bulb at the bottom, with a safety bulb at the top of the column.

Thermometers must not, of course, be overheated, even when they have a safety bulb. Neither must they be subjected to sudden and extreme changes of temperature, or heated over a naked flame. Often it is found that it is very difficult to see the graduation marks, especially when the thermometer is in some vessel. In such a case a good plan is to place a rubber band, or tie a piece of thread around the stem at the place indicating the temperature which is required.

It frequently happens that the mercury thread becomes detached and, as a rule, a smart swing or jerk is sufficient to re-unite the column. If this does not succeed, the thermometer should be heated in a water-bath, or placed inside a test-tube and the latter heated. This heating is continued until the safety bulb at the top is about half filled with mercury, when the liquid, or air, is allowed to cool gradually with the thermometer still in it. Usually the mercury is reunited on its return to the stem; if it is not, any mercury in the safety bulb should be coaxcd to the top of the column by a gentle tap or a shake, and the operation repeated until successful.

If desired, the thermometer may be calibrated from time to time. Most text-books on physics give instructions on this point.

CHAPTER III

THE PREPARATION AND STORAGE OF REAGENTS

IN the list which follows, the names of the substances are arranged in alphabetical order. Mention of many common substances has been omitted, chiefly because their use and storage present no special difficulty. When the substance is used in solution, the method of preparing the solution has been given except in such cases where a solution can be made by dissolving the appropriate amount of the solid in water, and no special instructions are necessary.

The strength of each particular solution used in qualitative analysis is largely a matter for the master in charge of the laboratory to decide. There appear to be at least three systems in common use :

The Arbitrary system.

The Twice Normal system.

The Three Times Normal system.

In the first of these the concentration of each solution is quite arbitrary, following no particular rule or plan, provided only that the solutions are strong enough, or weak enough, for the purpose for which they are intended. The other two systems, which seem more rational and convenient, are based on stiochiometrical relations. Thus, the common acidic and alkaline solutions, solutions of sodium and ammonium salts are, with few exceptions, made

two or three times normal strength. All other solutions are approximately normal, excepting solutions of expensive substances, concentrated acids and slightly soluble substances.

Under these systems equal volumes of different solutions contain the equivalent weight of the solid, or else some weight in some simple ratio to the equivalent. It is thus easy to calculate the approximate volume of solution to use in certain reactions and so avoid waste. Moreover, the master can readily recall the strength of any solution in his laboratory. Generally speaking, twice normal solutions are strong enough for school laboratory purposes, and this is commonly adopted.

The quantity of solution required varies with each particular teacher and laboratory; previous experience has to be the guiding factor. For most laboratories it is convenient to make some 10 litres of the following at a time—all dilute acids, ammonium hydroxide, chloride, and carbonate, and sodium hydroxide. This large quantity may be stored in large aspirators furnished with a stopcock at the bottom. In the case of sodium and ammonium hydroxides, a clip and rubber tube should be used instead of the glass tap, since the carbonate will form around the glass tap and cement it fast. Earthenware aspirators are considerably cheaper and quite as suitable as glass, the only difficulty being in seeing what quantity remains in the bottle. This can be easily overcome by inserting a glass tube, bent at right angles, through the bottom stopper to serve as a gauge. It is also necessary to cut a groove in the cork at the top of the aspirator, or employ some similar device to admit a little air, *e.g.* a tube of soda lime; if this is not done, the solution will not flow out of the tap. For most of the other reagents a Winchester quart bottle holds sufficient, and, in

some cases, sufficient to fill the bench bottle only should be made.

On the containing vessel, no matter of what kind, should be marked the volume it holds and the weight of the solid to be dissolved in that volume, or else the volume of concentrated solution necessary. This is for future use, when much time and work is thus avoided. Duro ink, a special marking pencil, or more simply a label, may be employed for this purpose. It is not necessary to weigh out the substances very accurately, and a pair of rough scales, weighing up to 2 kilograms and costing about £3, is useful.

In the account which follows, the equivalent weight has been given in most cases. This is the weight to be dissolved in a litre of distilled water to yield a normal solution. Distilled water should always be used in preparing these solutions. The quantity required to make 1 litre of normal solution has been given throughout, so as to make these notes convenient, no matter which system is employed in any particular laboratory. When the substance is not sufficiently soluble to make a normal solution this fact has been mentioned.

Attention is drawn to Appendix I, where the quantities required in all three systems have been summarized for the convenience of the laboratory assistant.

Acetic Acid.— CH_3COOH . M. Wt. 60. Eq. Wt. 60. Glacial acetic acid is the variety usually purchased and contains 98.9 per cent. by weight of CH_3COOH . One litre contains 1,045 grams of acetic acid. It is therefore $1045/60 = 17.4$ normal.

Concentrated acetic acid is made by diluting the glacial acid three times its volume with water.

To prepare a litre of approximately normal acid, $1000/17.4 = 58$ c.c. of glacial acid are required.

Care is necessary in thawing the acid, which solidifies in cold weather. It must be done gradually, a good method being to place the bottle, with its stopper removed, near the radiator.

Acetone (Acetic Ketone, Dimethyl Ketone).— CH_3COCH_3 . M. Wt. 58. Acetone is very volatile and inflammable and should be stored in well-stoppered bottles in a cool place.

Alcohol: Absolute.— $\text{C}_2\text{H}_5\text{OH}$. M. Wt. 46. This is used as purchased. It should then contain not more than 1 per cent. of water. It is very hygroscopic and must be kept in a well-stoppered bottle (see p. 102).

Alcohol: Rectified Spirit.—Rectified spirit contains 90 per cent. by volume or 85.68 per cent. by weight of ethyl alcohol, the remainder being water. It should be stored like absolute alcohol (see p. 102).

Alcohol: Industrial Methylated Spirit.—See p. 123.

Aluminium.—The most convenient form to purchase is turnings or chips. Aluminium wire is useful for making riders for balances, etc.

Ammoniacal Cuprous Chloride.—Dissolve 250 grams of ammonium chloride in 750 c.c. of water and to it add 200 grams of cuprous chloride. Shake the vessel until the cuprous chloride has dissolved and then add 250 c.c. of ammonium hydroxide, prepared by adding 60 c.c. of liquor ammoniae fortis to 190 c.c. of water. A long spiral of copper wire placed in the solution prevents oxidation.

Ammonium Acetate.— $\text{CH}_3\text{COONH}_4$. M. Wt. 77. Eq. Wt. 77. This is a very deliquescent substance; the crystals contain no water of crystallization and are very soluble. The substance becomes acidic on standing in air and ammonia is given off.

Ammonium Carbonate.—The substance sold under this name is a mixture of ammonium bicarbonate (NH_4HCO_3) and ammonium carbamate

($\text{NH}_2\text{NH}_4\text{CO}_2$), and contains approximately 31 per cent. NH_3 and 56 per cent. of CO_2 . The "molecular" weight can be taken as approximately 79.

Dissolve 80 grams in a solution of ammonium hydroxide, prepared by adding 60 c.c. of liquor ammoniac fortis to 500 c.c. of water, and make up to a litre with water. Filter it if necessary.

The solid effloresces when exposed to air and loses ammonia and carbon dioxide. It should be kept in a well-stoppered bottle in a cool place.

Ammonium Chloride. Sal ammoniac.— NH_4Cl . M. Wt. 53.5. Eq. Wt. 53.5. Only the pure variety should be used, since commercial ammonium chloride contains numerous impurities.

Ammonium Hydroxide.— NH_4OH . M. Wt. of NH_3 , 17. Eq. Wt. 17. Liquor ammoniac fortis, of specific gravity 0.88, is the kind purchased. One litre of it contains 315 grams of NH_3 and is therefore $315/17 = 18.5$ normal, and a litre of the normal solution requires $1000/18.5 = 54$ c.c. of the strong solution.

The liquor fortis loses ammonia very readily and has an overpowering pungent smell. It should be stored in a well-stoppered glass bottle in a cool place. Great care must be exercised when handling the solution and especially when opening the bottle, owing to the nature of the fumes evolved.

Ammonium Molybdate.—This is a complex substance with a probable formula $(\text{NH}_4)_6\text{Mo}_7\text{O}_{24} \cdot 4\text{H}_2\text{O}$. A solution of it is prepared by dissolving 75 grams of ammonium molybdate in 75 c.c. of strong ammonium hydroxide (50 c.c. of liquor fortis to 25 c.c. of water). The solution is then made up to 500 c.c. with distilled water and poured into 500 c.c. of nitric acid of approximately five-normal strength. After heating for ten minutes the solution is decanted off and, if necessary, filtered.

A solution of ammonium molybdate does not keep

a long time, and hence it is not advisable to prepare more than a litre at a time. It should be placed in a dark bottle and inspected occasionally, and if any precipitate has separated out the clear solution should be decanted ready for future use.

Ammonium Nitrate.— NH_4NO_3 . M. Wt. 80. Eq. Wt. 80. A stock of the commercial variety is useful for the preparation of freezing mixtures.

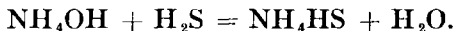
Ammonium Oxalate. — $(\text{NH}_4)_2\text{C}_2\text{O}_4 \cdot \text{H}_2\text{O}$. M. Wt. 142. Eq. Wt. 71. The crystals are not very soluble, hence the bench solution is prepared by dissolving 35.5 grams in 1 litre of water.

Ammonium Sulphate.— $(\text{NH}_4)_2\text{SO}_4$. M. Wt. 132. Eq. Wt. 66. This substance is not used frequently in an ordinary laboratory except in the preparation of alums and ferrous ammonium sulphate. It contains no water of crystallization.

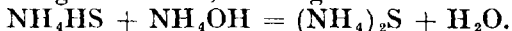
Ammonium Sulphocyanide.— NH_4CNS . M. Wt. 76. Eq. Wt. 76. See Potassium Sulphocyanide.

Ammonium Sulphide. Yellow ammonium sulphide.—When purchased the solution should be clear and colourless, or at the most only slightly yellow.

It may be prepared by saturating an approximately five normal solution of ammonium hydroxide with hydrogen sulphide gas, when ammonium hydro-sulphide is formed.



Then an equal volume of ammonium hydroxide of the same strength is added, forming ammonium sulphide.



The solution oxidizes on exposure to air and free sulphur is formed. This dissolves, forming a polysulphide $(\text{NH}_4)_2\text{S}_x$, where x is any number from one to nine. After a time some ammonium thiosulphate, $(\text{NH}_4)_2\text{S}_2\text{O}_3$, is formed and finally sulphur is deposited. When this occurs, the solution is of little use for analytical work and should be thrown away.

Ammonium sulphide can be used as purchased or prepared, or alternatively, diluted three times. It should be kept in small well-stoppered bench bottles containing only a little of the solution.

Aniline.— $C_6H_5NH_2$. M. Wt. 93. Aniline is a colourless liquid which readily turns yellow to brown on exposure to light. It should be kept in a dark bottle.

Antimony.—Antimony metal can be easily powdered in the mortar when necessary, *e.g.* to illustrate the properties of chlorine.

It is useful to have its soluble salts, potassium antimoniate and antimonite, as well as tartar emetic (potassium antimonyl tartrate), its oxides and sulphides (both polymorphic varieties).

Aqua Regia.—This should be prepared as required by adding 3 parts by volume of concentrated hydrochloric acid to 1 of nitric acid.

Arsenious Oxide.— As_2O_3 . M. Wt. 197.9. Eq. Wt. 49.48. Arsenious oxide should be bought pure for volumetric work (see p. 74).

Potassium arsenite and arsenate are soluble in water and are useful for practice in analysis.

Care is necessary in storing all arsenic as well as antimony salts owing to their poisonous nature. The fumes given off in many of the tests for arsenic, *e.g.* the cacodyl test, are also very poisonous.

Asbestos Filters (for use with Gooch crucibles, etc.).—Pure white asbestos, long fibred and soft, is the best kind for this purpose. Cut the fibres into small pieces about $\frac{1}{4}$ -in. in length, add to them concentrated hydrochloric acid and digest on the water-bath for an hour. Filter and wash the asbestos at the pump. If preferred, it may now be stored dry until required for use; otherwise, it is placed in the storage bottle, covered with water and well shaken until it forms a sludge.

Barium Chloride.— $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$. M. Wt. 244.3.
Eq. Wt. 122.15.

Barium Hydroxide.—See p. 75.

Barium Nitrate.— $\text{Ba}(\text{NO}_3)_2$. M. Wt. 261.4.
Eq. Wt. 130.7. This substance is not very soluble (about 1 in 14), and therefore a semi-normal solution is employed, *i.e.* dissolve 65 grams in a litre of water.

Benzoic Acid.— $\text{C}_6\text{H}_5\text{COOH}$. M. Wt. 122. Eq. Wt. 122. Benzoic acid is affected by the light and air and should therefore be stored in a dark bottle which is well stoppered.

Bleaching Powder. Chloride of Lime.—On exposure to air, bleaching powder becomes moist and loses chlorine. The latter also takes place after a time, no matter how the powder is stored. It should be kept in well-stoppered bottles. Bleaching powder contains at least 30 per cent. of available chlorine, but a freshly prepared sample should contain a greater percentage than this.

It is a useful substance from which a solution of calcium hypochlorite can readily be obtained. One part by weight of the powder is mixed with a little water and ground in the mortar to a cream. Sufficient water to make 10 parts is added and the solution filtered free from the lime.

Borax. Biborate of Sodium.— $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$.

Refined borax is used in analysis. It is somewhat efflorescent.

Bromine.—Bromine gives off red fumes when exposed to the air. It must be kept in a well-stoppered bottle and care exercised when opening it, since it may cause very dangerous burns and is very volatile. The substance should always be weighed in a stoppered vessel.

Bromine Water.—Only a little of this is required in a school laboratory. It is best made when required by adding bromine drop by drop to distilled

water, and shaking it vigorously after each addition, until a saturated solution is obtained.

Calcium Carbonate.— CaCO_3 . M. Wt. 100. Eq. Wt. 50. The purest form is that obtained from Iceland spar or marble.

Calcium Chloride.— CaCl_2 . M. Wt. 111. Eq. Wt. 55.5. The crystalline variety contains six molecules of water of crystallization. Calcium chloride, pure dry granulated, or pure fused, is used for drying gases. It is very deliquescent.

Calcium Hydroxide. Lime Water.—This is prepared by dissolving quick or slaked lime in water. Slake 20 grams of calcium oxide with water. Owing to the large amount of heat evolved, this operation is best carried out on a clean piece of wood. Place the lime in a Winchester bottle and add about 2 litres of distilled water and shake it. Allow the contents to remain in contact with the water and give the bottle occasional shakings. Decant off the supernatant liquid. It is very convenient to keep about 2 litres of water always in the stock bottle and the assistant should shake the bottle at various odd times. Lime is more soluble in cold than in hot water. Owing to its readiness to absorb carbon dioxide, lime water is kept in rubber-stoppered bottles.

Calcium Sulphate.— $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$. M. Wt. 172. Eq. Wt. 86. This substance is only slightly soluble in water. A solution is prepared by adding a few grams of the solid to a Winchester bottle full of water and shaking the bottle vigorously. The solution is decanted off into the bench bottle, and more water added to the Winchester so that the solid remains in contact with the water for a considerable time.

Carbon Bisulphide.—This liquid must be handled with care. It is very inflammable and readily forms an explosive mixture with hot air; it therefore should not be placed near a lighted gas burner.

Carbon Dioxide.—Carbon dioxide can be purchased, if desired, in steel cylinders, which must be kept in a very cool place. In most school laboratories a convenient supply can be obtained from Kipp's Apparatus, using marble chips and hydrochloric acid.

Chlorine Water.—Chlorine is only slightly soluble in water, hence a saturated solution is prepared by bubbling chlorine through distilled water. The chlorine gas is readily prepared by dropping concentrated hydrochloric acid on crystals of potassium permanganate and bubbling the gas through water to absorb any hydrogen chloride. A saturated solution contains about 0.5 per cent. of chlorine when freshly prepared, but it is unstable and is best prepared when required. When stored, it must be kept in a dark bottle.

Chloroform.—Chloroform should be stored in a dark-coloured bottle in a cool place.

Cobalt Nitrate. Cobaltous Nitrate.— $\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$. M. Wt. 290.9. Eq. Wt. 145.5. The solid is very deliquescent.

Copper.—Copper may be purchased in the form of foil, wire, turnings, or in the powdered state (reduced copper). Of these the turnings are the most convenient for the school laboratory. Reduced copper can be made when required by acting on a warm saturated solution of copper sulphate with small pieces of zinc foil. When all the copper has been precipitated, the supernatant liquid is poured off and the copper thoroughly washed, first with water and then with alcohol or methylated spirit. The spirit is then allowed to evaporate away by placing the containing vessel in a warm place. The copper is dried finally in a desiccator.

Copper Oxide.—Copper oxide is slightly hygroscopic and before use in quantitative experiments should be dried by heating it in a crucible.

Copper Sulphate.—Crystals of blue vitriol,

$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, effloresce very slowly if kept in a dry place.

To prepare anhydrous copper sulphate, crystals of blue vitriol are crushed in the mortar and heated in an air-oven at about 210°C . The substance should not be heated to a higher temperature or black copper sulphide may be formed, whilst at a lower temperature all the water is not driven off.

Dimethylglyoxime.— $(\text{CH}_3\text{CNOH})_2$. A 1 per cent. solution is strong enough for detecting the presence of nickel. Dissolve 10 grams in a litre of rectified spirit or industrial methylated spirit.

One ounce of this substance lasts a considerable time.

Diphenylamine.— $(\text{C}_6\text{H}_5)_2\text{NH}$. 4.5 grams of the solid are dissolved in a mixture of 850 c.c. of concentrated sulphuric acid to 150 c.c. of water.

Ether. Sulphuric Ether, Ethyl Oxide.— $(\text{C}_2\text{H}_5)_2\text{O}$. Ether is a very inflammable liquid which gives off a very heavy vapour. It must be kept in a dark, well-stoppered bottle in a cool place.

When ether is being recovered by distillation the collecting vessel should be placed at a lower level than the bunsen burners, *e.g.* in the sink. Unless this is done the ether vapour may travel on the bench top to the bunsen; it is heavier than air.

Ethyl Acetate. Acetic Ether.—This is treated in a similar manner to ether.

Ethyl Chloride and other Ethyl Alcohol Derivatives.—All these substances are best stored in dark bottles in a cool place, or else in sealed tubes.

Ethyl Iodide.—Ethyl iodide soon turns brown on keeping. This can be prevented by adding in the bottle a few c.c. of mercury. A discoloured solution should be shaken up with finely powdered sodium bisulphite, filtered and redistilled.

Fehling's Solution.—This solution is best made in two parts, each solution being kept in separate bottles until required.

Solution A is prepared by dissolving 69.28 grams of blue vitriol in distilled water to which have been added a few c.c. of concentrated sulphuric acid, to prevent the formation of any basic salt. The solution is made up to a litre with distilled water.

Solution B is prepared by dissolving 352 grams of sodium potassium tartrate (Rochelle Salt) and 154 grams of sodium hydroxide in water, and making up to a litre.

When required, equal volumes of both solutions are mixed together and a clear dark blue solution should result.

Both bottles should be well stoppered.

Ferric Chloride.— $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$. M. Wt. 270.5. Eq. Wt. 90.2. It may be necessary to filter after the solid has been dissolved in the requisite amount of water.

Ferrous Ammonium Sulphate.— $\text{FeSO}_4(\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$. This substance keeps indefinitely.

Ferrous Sulphate.— $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$. M. Wt. 278. Eq. Wt. 139. Only the purest variety should be purchased since impure crystals oxidize readily. When pure the substance keeps a considerable time if the bottle is well stoppered. Solutions of this salt should be made immediately before use. The crystals should be powdered and dissolved in freshly boiled distilled water *which has been cooled*.

Ferrous Sulphide.— FeS . This is the sulphide used in the preparation of hydrogen sulphide. It is purchased in metallic-looking sticks.

Fusion Mixture.—This is a mixture of sodium carbonate and potassium carbonate or cyanide in proportion to their equivalent weights, *e.g.* approximately 10 parts by weight of anhydrous sodium carbonate to 13 parts by weight of anhydrous potassium carbonate.

Glycerin. Glycerol.— $\text{C}_3\text{H}_8(\text{OH})_3$. Glycerin is

$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, effloresce very slowly if kept in a dry place.

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One ounce of this substance lasts a considerable time.

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Ether. Sulphuric Ether, Ethyl Oxide.— $(\text{C}_2\text{H}_5)_2\text{O}$. Ether is a very inflammable liquid which gives off a very heavy vapour. It must be kept in a dark, well-stoppered bottle in a cool place.

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When required, equal volumes of both solutions are mixed together and a clear dark blue solution should result.

Both bottles should be well stoppered.

Ferric Chloride.— $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$. M. Wt. 270.5. Eq. Wt. 90.2. It may be necessary to filter after the solid has been dissolved in the requisite amount of water.

Ferrous Ammonium Sulphate.— $\text{FeSO}_4(\text{NH}_4)_2 \cdot 6\text{H}_2\text{O}$. This substance keeps indefinitely.

Ferrous Sulphate.— $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$. M. Wt. 278. Eq. Wt. 139. Only the purest variety should be purchased since impure crystals oxidize readily. When pure the substance keeps a considerable time if the bottle is well stoppered. Solutions of this salt should be made immediately before use. The crystals should be powdered and dissolved in freshly boiled distilled water *which has been cooled*.

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Fusion Mixture.—This is a mixture of sodium carbonate and potassium carbonate or cyanide in proportion to their equivalent weights, *e.g.* approximately 10 parts by weight of anhydrous sodium carbonate to 13 parts by weight of anhydrous potassium carbonate.

Glycerin. Glycerol.— $\text{C}_3\text{H}_5(\text{OH})_3$. Glycerin is

hygroscopic and should be stored in a well-stoppered bottle.

Hydrochloric Acid.— HCl . M. Wt. 36.47. Eq. Wt. 36.47. The concentrated acid, as purchased, has a specific gravity of 1.16 and contains 31.52 per cent. by weight of HCl , that is, 366 grams per litre. It is therefore $366/36.47 = 10.03$ normal. To prepare an approximately normal solution, $1000/10.03 = 99.7$ c.c. of the acid are diluted to one litre.

The commercial acid contains, amongst other things, iron, sulphuric acid, chlorine and arsenic, but is sufficiently pure for use in Kipp's Apparatus when a five-normal solution is employed.

Hydrogen Peroxide.— H_2O_2 . A solution of twenty-volume strength is usually purchased which contains approximately 6 per cent. by weight of H_2O_2 . It should be kept in a dark bottle, since it readily decomposes on exposure to light and warmth. "Perhydrol" is a hundred-volume strength solution.

Hydrogen Sulphide.— H_2S . The gas is obtained from a Kipp's Apparatus. When a solution is required, the gas from the Kipp's Apparatus is washed by passing it through a small amount of water.

Indicators.—See p. 75.

Iodine.—The solid is volatile even at ordinary temperatures and should be kept in a well-stoppered glass bottle with a glass stopper.

A solution can be prepared by dissolving 1 gram of iodine and 3 grams of potassium iodide in 50 c.c. of water.

Iron.—Iron wire practically pure can be purchased for volumetric work. Such wire will rust in a moist atmosphere. It should be kept in a vessel in which there are a few lumps of quicklime.

Lead Acetate. Sugar of Lead.— $(\text{CH}_3\text{COO})_2\text{Pb} \cdot 3\text{H}_2\text{O}$. M. Wt. 379.2. Eq. Wt. 189.6. This is one of the few soluble lead salts. The solid should

be kept in a well-stoppered bottle. Lead acetate papers are made by soaking filter papers in a solution of lead acetate, drying them and cutting them into strips.

Lime Water.—See Calcium Hydroxide, p. 60.

Magnesium.—Magnesium readily oxidizes when exposed to moist air. The ribbon should be kept in waxed paper, or else in a bottle containing quicklime.

Manganese Dioxide. Pyrolusite.— MnO_2 . A good sample of powdered pyrolusite contains 80 to 90 per cent. of MnO_2 . Granulated manganese dioxide is the best variety to use in the preparation of chlorine.

Mercury.—Pure redistilled is the kind usually purchased for school use. It should be stored in a strong earthenware bottle, and, owing to its great density, boys should be cautioned of the unexpected weight of the bottle before lifting it. Mercury should not be poured into a thin-walled glass vessel, and whenever it is being used, the apparatus, etc., containing the mercury should be placed on a tray to catch any mercury which may be spilt (see p. 26).

Mercuric Chloride. Mercury Bichloride, Corrosive sublimate.— HgCl_2 . M. Wt. 271.5. Eq. Wt. 135.7. (See also p. 107.) Mercuric chloride is only slightly soluble in water and therefore a fifth-normal solution is usually employed. It is a very poisonous substance and should be labelled as such. Powdered mercuric chloride (B.P. Pulv.) is the most suitable form to purchase.

Microcosmic Salt. Sodium Ammonium Phosphate.— $\text{NaNH}_4\text{HPO}_4 \cdot 4\text{H}_2\text{O}$. This salt is frequently used in place of borax in the blowpipe reactions.

Nessler's Reagent.—This is an alkaline solution of potassium and mercuric iodide. Dissolve 3.5 grams of potassium iodide in about 10 c.c. of water. Grind 1.25 grams of mercuric chloride to a fine powder in the mortar, add the potassium iodide solution to this and grind them until all the chloride has dis-

solved. Transfer the solution with the washings to a beaker (the total solution should not exceed 50 c.c.). To this add a saturated solution of mercuric chloride until a faint red precipitate persists, and then add 12 grams of sodium hydroxide and apply heat to dissolve this, if necessary. When it is cool add one or two drops of the mercuric chloride solution until a precipitate is formed again. Dilute to 100 c.c. and pour the supernatant liquid into the storage bottle, which should be a dark one with a rubber stopper.

The solution deteriorates on keeping.

Nitric Acid.— HNO_3 . M. Wt. 63. Eq. Wt. 63. The concentrated acid has a specific gravity of 1.420 and contains 69.8 per cent. of HNO_3 . One litre contains 991 grams and is therefore $991/63 = 15.7$ normal. Hence $1000/15.7 = 63.6$ c.c. of the acid is required to make 1 litre of normal acid.

The commercial acid contains, amongst other things, hyponitric acid, chlorine, sulphuric acid and iron.

Phenol. Carbohic Acid.— $\text{C}_6\text{H}_5\text{OH}$. M. Wt. 94. Eq. Wt. 94. Carbohic acid crystals turn a pink colour on exposure to air, and are deliquescent, forming a crystalline hydrate, $2.\text{C}_6\text{H}_5\text{OH}.\text{H}_2\text{O}$. They should be kept in a well-stoppered dark bottle.

Phosphorus.—A school laboratory usually possesses both red and white phosphorus.

The red amorphous variety is stored in a well-stoppered bottle and few precautions are necessary in using it.

The white (yellow or waxy) phosphorus is kept under water in a glass bottle. When using it, the phosphorus should be withdrawn by means of the crucible tongs and placed in an evaporating vessel containing water. The phosphorus should be cut while under the water and placed on a filter paper to dry. This allotropic form must never be touched

by the hands, especially when dry. The heat of the body is sufficient to ignite the phosphorus.

Phosphorus Derivatives.—Most of these, especially the chlorides, oxides, and the acids, are effected by the moisture of the air and should be kept in well-stoppered bottles.

Picric Acid.—See p. 108.

Platinic Chloride. Platinum Bichloride.— $\text{PtCl}_4 \cdot 2\text{HCl}$. M. Wt. 409.2. This is a very hygroscopic substance and must be kept in a sealed glass tube.

A suitable solution for qualitative work is made by dissolving 5 grams of the substance in 100 c.c. of distilled water.

Platinized Asbestos.—Asbestos fibre is cleansed and dried and then immersed in a strong solution of platinic chloride—2.5 grams of $\text{PtCl}_4 \cdot 2\text{HCl}$ in 20 c.c. water. The asbestos is then placed in a solution of ammonium chloride, when ammonium chloroplatinate is formed as a deposit on the asbestos. The latter is now strongly heated, when the chloroplatinate decomposes and leaves a layer of finely divided platinum on the asbestos.

Platinum Wire.—A lead pencil, sharpened to a long chisel point, makes a good substitute for platinum wire.

Potassium.—See Sodium, p. 69.

Potassium Chlorate.— KClO_3 . This substance must be handled very carefully. It readily evolves oxygen and should never be ground in the mortar, etc., with any other substance which is easily oxidized or inflammable, or with sulphur, carbon, or antimony sulphide. Indeed, the safest plan is to grind the chlorate separately before mixing it with any other substance.

Potassium Cyanide.— KCN . There are many varieties of this very poisonous substance on the

market. Potassium cyanide of commerce, containing 90 per cent. of KCN, is usually purchased.

Most samples decompose on keeping, with the formation of hydrogen cyanide. Hence the substance should not be smelled. A solution of it also decomposes, forming a flocculent precipitate, and should therefore be made immediately before use.

Potassium Ferricyanide.— $\text{K}_3\text{Fe}(\text{CN})_6$. M. Wt. 329. Eq. Wt. 329. A solution of this is not very stable and should be made when required. Dust and light cause the crystals to be reduced on the surface to the ferrocyanide; thus the crystals should be rinsed before using and the solid kept in a dark, well-stoppered bottle.

Potassium Ferrocyanide.— $\text{K}_4\text{Fe}(\text{CN})_6 \cdot 3\text{H}_2\text{O}$. M. Wt. 422 Eq. Wt. 422. To prepare a solution of this, 211 grams of the crystals are dissolved in a litre of water. A piece of iron wire placed in the solution helps to preserve the latter.

The solid is slightly efflorescent and should be kept well stoppered.

Potassium Hydroxide.—See Sodium Hydroxide, p. 70.

Potassium Iodide.—KI. M. Wt. 166. Eq. Wt. 166. Owing to the cost of this substance, a fifth-normal solution is usually employed. The solution is best kept in a dark bottle, but even then the solution gradually turns yellow. This can be prevented by adding a few c.c. of mercury to the solution.

Potassium Permanganate.—A decinormal solution is employed as a test reagent (see p. 73).

Potassium Sulphocyanide.—KCNS. M. Wt. 97. Eq. Wt. 97. Potassium sulphocyanide is very sensitive to ferric salts and a fifth-normal solution is strong enough. The solid is very deliquescent and so the bottle must be well stoppered. Ammonium sulphocyanide may be used instead of the potassium salt.

Silver Nitrate.— AgNO_3 . M. Wt. 170. Eq. Wt. 170. Distilled water must always be used to prepare a solution of this salt. A fifth-normal solution is strong enough for bench purposes. The solution is partially decomposed by light and should be kept in dark bottles.

Soda Lime.—As its name suggests, this is a mixture of caustic soda and slaked lime. It should be kept in a bottle with a waxed cork.

Sodium and Potassium.—Both these metals readily oxidize in air and are kept under naphtha (or toluene, or xylene). It has been stated that when these metals have been stored in this manner they may cause an explosion when thrown into water, and that the naphtha is in some way the cause of this. Others explain the explosion as being due to the use of pure metal.

An alternative method is to keep these metals, especially sodium, in an ordinary bottle, when it is necessary to cut off the outer crust before using. If desired, an amalgam of the metal with mercury may be used; this acts less vigorously than the pure metal.

These metals should not be handled with wet fingers, or by those people who are prone to perspire. It is always best to avoid direct handling, and to cut the metal on a dry filter paper.

Any residues must not be placed in the sink, for fear of an explosion, but should be added in small pieces to acetone, allowing each piece to dissolve before further addition. This solution may then be poured down the sink.

Sodium Amalgam.—Gently warm a known weight of mercury and place it in a mortar. To this add approximately $\frac{1}{10}$ th by weight of sodium cut into small pieces. The experiment should be performed in the fume cupboard and the hand protected by gloves, or by a duster. If preferred, the

sodium may be thrust under the surface by means of a glass rod. The amalgam should be protected from moisture and from the air.

Sodium Acetate.— $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$. M. Wt. 136. Eq. Wt. 136. This is an efflorescent substance. A saturated solution is the most efficient for the phosphate separation. Indeed, the solid itself may be used for this purpose.

Sodium Cobaltinitrite.—40 grams of cobalt nitrate crystals and 100 grams of sodium nitrite are dissolved in 500 c.c. of water, 20 c.c. of acetic acid added and the solution diluted to 1 litre. Such a solution keeps about three months. A few drops of acetic acid may be added to it occasionally.

Sodium Hydroxide.— NaOH . M. Wt. 40. Eq. Wt. 40. There are at least three important varieties on the market—sodium hydroxide pure from sodium, pure by alcohol, and pure. The first variety is somewhat expensive and is only used, in school laboratories, for very accurate volumetric work. Indeed, the variety “pure by alcohol” is quite pure enough for this purpose, but “sodium hydroxide pure” is used for preparing the bench solutions. All varieties are very deliquescent and also readily absorb carbon dioxide from the air; they should be stored accordingly. Owing to its caustic action, the substance should not be touched by hand.

Glass wool should always be used when filtering a solution of this solid, since the alkali attacks and dissolves filter paper. The solution should be kept in rubber-stoppered bottles; otherwise sodium carbonate forms around the stopper and cements it fast. The rubber stoppers are attacked slowly.

When sodium hydroxide is used in a burette, and this should occur on very few occasions, great care should be exercised in seeing that the burette is thoroughly washed out after use, especially round the tap.

Sodium Nitro Prusside.—A freshly prepared solution should always be used containing 2.5 grams per 100 c.c. of water.

Sodium Phosphate.— $\text{Na}_2\text{HPO}_4 \cdot 12\text{H}_2\text{O}$. M. Wt. 358. Eq. Wt. 119.3. The substance going under this name is chemically disodium hydrogen phosphate.

A trace of chloroform in the solution will prevent growth of fungi.

Stannous Chloride.— $\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$. M. Wt. 225.6. Eq. Wt. 112.8. Dissolve the gram equivalent weight in a litre of normal hydrochloric acid and filter.

A better method is to heat 100 grams of granulated tin with a mixture of 300 c.c. of concentrated hydrochloric acid and 50 c.c. of water until no gas is evolved. If the solution is still acid, more tin must be added and the treatment continued until the tin is present in excess. Any undissolved tin should be left in the solution when storing it.

Sulphuric Acid.— H_2SO_4 . M. Wt. 98. Eq. Wt. 49. The specific gravity of concentrated sulphuric acid is 1.843, and there are two concentrations of acid which have this specific gravity—acid containing 95.9 per cent. and that with 99 per cent. by weight of H_2SO_4 . Assuming the acid contains 96 per cent. by weight, then there will be 1769.3 grams H_2SO_4 per litre. Hence the acid is $1769.3/49 = 36$ times normal strength and $1000/36 = 28$ c.c. are required to form a litre of normal acid.

The acid is sometimes used as purchased as bench concentrated acid, but, owing to its vigorous nature, it appears undesirable to put such an acid within reach of children and such acid should be kept on the "side" shelves.

Concentrated acid should always be added very gradually to water, for the heat of solution is very great. This addition is best carried out in an earthenware jug, or pneumatic trough, or some vessel which

can withstand great heat. On no account should water be added to the acid.

Twice-normal acid is not strong enough for some reactions, *e.g.* the preparation of hydrogen from zinc, or equivalent weight determinations. In such cases five-normal acid should be used.

Commercial acid contains, amongst other things, arsenic, lead, iron, and the oxides and acids of nitrogen.

Solutions for Volumetric Work

The amount of volumetric work done in schools seems to be on the increase, and in many schools some litres of the commoner solutions are used each term. The preparation of these involves much work to the assistant, and partly to avoid this it is advisable to prepare some 10 litres or so of each solution at the beginning of the term and store them in large aspirators furnished with a stopcock. This can only be done in those cases where the solution does not deteriorate on standing. For their preparation there should be available a very accurate set of standardized apparatus.

Acids and Alkalies.—The theoretical basis for acidimetry and alkalimetry is a standard solution of sodium carbonate, since this substance can be prepared pure by heating sodium bicarbonate until there is no further loss in weight. This solution is then used to standardize the acids, and they in turn to standardize the remaining alkalies. The busy master with little or no assistance will probably find it more convenient to buy, ready standardized, a litre of normal acid. Most dealers sell this; generally it has been very accurately standardized, and the cost is by no means excessive. This solution should be reserved solely for standardizing the laboratory volumetric solutions of alkalies, and hence, through the latter, any other acids.

Standard solutions of hydrochloric and sulphuric acids do not deteriorate on keeping. Thus, 10 litres of each may be prepared at a time and stored in an aspirator; grooves must be cut in the cork at the top to allow air to enter. If this is not done, the acid will not run out of the tap.

Even sodium hydroxide and sodium carbonate will keep under these conditions in a good enough condition for fifth-form work. If a more accurate method is preferred, the aspirator can be stoppered by a tight-fitting rubber bung through which passes a tube containing soda lime. The latter absorbs any carbon dioxide and so prevents contamination.

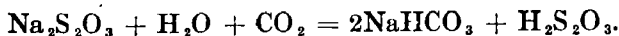
Potassium Permanganate can be bought sufficiently pure to use in the preparation of a standard solution. It is best, however, to prepare about 10 litres and then to standardize it against oxalic acid. Before doing so, the solution should be allowed to stand for a week or so until all the organic matter (which is present even in distilled water) has reacted with it. The solution should be usually about decinormal in strength, and such a solution will retain its strength for a term, if protected from light, dust and organic matter.

Potassium Bichromate is not so much used, and 2 litres are probably sufficient for most laboratories. A solution of this substance keeps indefinitely.

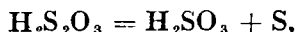
Silver Nitrate crystals can be bought pure, but a solution of silver nitrate does not keep for a long time, even in dark bottles. It is best to prepare it when required for sixth-form work. For fifth-form work sufficient for the term can be prepared at one operation.

Sodium Thiosulphate.—Crystals of sodium thiosulphate often contain more water than the formula, $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$, indicates. Thus an accurate standard solution cannot be made directly. To

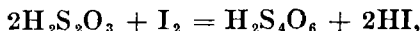
prepare a litre of decinormal solution, about 26 grams of the crystals are dissolved in a litre of water and this solution then standardized against a known iodine solution. A thiosulphate solution becomes stronger with regard to iodine on keeping. This apparently strange occurrence is probably due to the carbon dioxide reacting with the hypo, forming thio-sulphuric acid, thus :



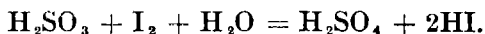
The thiosulphuric acid then decomposes, forming sulphurous acid and sulphur, thus :



and the sulphurous acid reacts with more iodine than a corresponding amount of thiosulphuric acid does. That is, one molecule of the thio-acid requires one atom of iodine,



whereas one molecule of sulphurous acid (which is formed from one of thiosulphurous acid) reacts with two atoms of iodine,



For ordinary school purposes, if the water is boiled vigorously before dissolving the hypo to drive off the carbon dioxide, sufficient solution for the term may be prepared.

Iodine.—A standard solution of iodine is made by dissolving the iodine in a solution of potassium iodide, from one and a half times to twice as much potassium iodide as the iodine being required. The solution goes weak on standing; hence no great quantity should be prepared at once, and the strength of the solution should be determined before each use.

Arsenious Oxide.—This substance is got into solution by dissolving the solid in a cold sodium

carbonate solution, or better, one of the bicarbonate. Such a solution keeps sufficiently well for school purposes.

Barium Hydrate.— $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$. This substance may be bought either in the crystalline form or fused. The crystals are occasionally a slight yellow colour, and should then be recrystallized from water. It is only very slightly soluble in water, and a decinormal solution, or weaker, is generally used. It readily absorbs carbon dioxide, and hence must be kept in well-stoppered bottles.

The Preparation of Indicators

Litmus.—Litmus is purchased in the form of small dark-blue cubes. 100 grams of the cubes are finely powdered in the mortar and digested repeatedly with distilled water until no more of the litmus dissolves. The whole of the solution is next evaporated to a small volume and dilute acetic acid added until no further effervescence takes place; this treatment decomposes any carbonate. The solution is then heated again until it becomes pasty. Excess of warm alcohol is added to this paste and this precipitates the blue colouring matter. After filtering the mixture, the precipitate is digested for some time with a litre of water.

Litmus goes bad when kept out of contact with air; therefore it should be kept in a wide-mouthed bottle and grooves cut down the sides of the cork. A few drops of chloroform may be added to prevent any growth of fungi.

Methyl Orange.—Since half an ounce will be sufficient for an ordinary laboratory for years, only the purest kind should be bought. One gram of the solid is dissolved in a litre of water.

Phenol Phthalein.—Once again, half an ounce is sufficient for a number of years. It is nearly insoluble

in water, but is soluble in alcohol. 2 grams of the solid are dissolved in 600 c.c. of rectified spirits (or industrial methylated spirit), and distilled water is added to make 1 litre.

Potassium Chromate.—Dissolve 50 grams of the crystals in 1 litre of distilled water.

Starch Solution.—About 1 gram of starch is mixed with a little cold water in a mortar and ground into a paste. This is poured, drop by drop, into about 100 c.c. of boiling water, which is stirred after each addition. Starch solution does not keep.

Starch Iodized Papers.—To the above solution add one of potassium iodide and dip into it strips of cartridge paper. Dry these and place in a stoppered bottle ready for use.

The Storage of Chemicals

Much time and trouble can be saved by adopting some uniform method of storage, and the master has at least three methods to choose from—the “alphabetical method,” the “family method,” or the “group method.”

In the first method all the bottles are arranged in the alphabetical order of the substances contained in them. Very frequently any deficiency in space can be overcome by storing the sodium, potassium and ammonium salts, which are by far the most numerous, in a separate cupboard or place.

In the second method, the chemicals are arranged according to the periodic classification, that is, all the alkali salts together, all the alkaline earth salts together, and so on.

In the third method, the order adopted is that of the groups in ordinary qualitative analysis, that is, the silver, lead and mercurous salts together, and so on.

It is necessary, in both the last two methods of storage that whoever goes to the storage cupboard or

shelves must have some knowledge of chemistry, either of the periodic classification, or of qualitative analysis, and for this reason the alphabetical method seems to be by far the most suitable. But whatever method is employed, great care has to be exercised that the bottles are returned to their correct places on the shelf after use, and a periodic inspection by the master is desirable.

One fault, common in many laboratories, is that of storing substances out of reach without the use of steps or chairs. Serious accidents may result from this, and large Winchester bottles of concentrated acids and the like should be kept on or near the floor. All the storage cupboards should be situated, if possible, in a special store-room. They should be kept as cool as possible, and the position of any radiators, etc., should be taken into consideration. Most of the chemicals ought to be kept under lock and key, especially those of a particularly poisonous nature. Indeed, many masters prefer to have a small "poison cupboard," the key of which is always in the master's possession.

Special precautions for preventing decomposition and for the storage of bench solutions have been mentioned under the names of certain substances. It now remains to deal with a few more general topics.

Deliquescent, hygroscopic and efflorescent substances should be stored in well-stoppered bottles. Those in common use may be placed in bottles with rubber bungs, or ground-glass stoppers, those less rarely used in bottles whose stopper, either bark or glass, is coated with lacquer, collodion, or paraffin wax. This coating must be renewed after each use. Volatile substances, such as carbon bisulphide, ether and most organic liquids, should be stored in a similar manner, or in a sealed glass tube.

The following is a list of the commoner deliquescent or hygroscopic substances :

Ammonium Acetate.	Ammonium Sulpho-
Barium Chloride.	cyanide (v).
All Bismuth salts, except the carbonate.	Barium Sulphide.
Bleaching Powder (s).	Calcium Chloride (v).
Calcium Oxide (v).	Calcium Nitrate (v).
Chromic Acid (v).	Chromium Sulphate (v).
Cobalt Acetate.	Cobalt Chloride.
Cobalt Nitrate (v).	Copper Chloride.
Copper Sulphate, anhydrous (v).	Ferric Chloride.
Ferrous Chloride (v).	Microcosmic Salt.
Magnesium Chloride (v).	Nickel Chloride (v).
Manganese Nitrate.	Platinic Chloride (v).
Phosphoric Acid (or P_2O_5).	Potassium Hydroxide (v).
Potassium Carbonate.	Potassium Sulpho-
Potassium Nitrate (s).	cyanide (v).
Potassium Quadroxalate (s).	Soda Lime (v).
Potassium Tartrate (s).	Sodium Bromide.
Sodium Carbonate (s).	Sodium Bichromate.
Sodium Hydroxide (v).	Sodium Iodide.
Sodium Nitrate.	Sodium Nitrite (s).
Sodium Sulphide (v).	Stannous Chloride.
Zinc Chloride.	Strontium Bromide.
	Zinc Nitrate.

v signifies very deliquescent.

s signifies slightly deliquescent or hygroscopic.

LIST OF EFFLORESCENT SUBSTANCES

Magnesium Sulphate Crystals.	Sodium Acetate (in warmth).
Sodium Carbonate Crystals (Washing Soda).	Sodium Sulphate (Glauber's Salts).
Sodium Phosphate.	

CHAPTER IV

THE PHYSICAL LABORATORY

AT one time there was a vigorous demand that students of science should construct most of their own apparatus for elementary work, and most text-books of physics gave elaborate instructions on the making of various pieces of apparatus. Unfortunately for this plan, the time at the disposal of the average physics master is scarcely enough for him to permit such work, which possibly belongs more to the school workshop than to the laboratory. There are, however, many admirable books on laboratory arts, mention of which will be found in the Preface. Hence this chapter will refer to the ordinary routine duties, arranged alphabetically.

The Amalgamation of Zinc and Copper.—Amalgams are solutions or alloys of metals in mercury, and are so called because the resulting product, owing to the excess of mercury used, is often a liquid (Amalgam = softening).

In certain experiments it is necessary to use "mercury cups," *i.e.* holes in pieces of wood, as connectors. These cups are connected together by thick copper wires. If these wires are amalgamated and thrust well into the mercury, the electrical resistance of the joint is almost negligible. The copper wires should first be cleaned with fine emery cloth, washed in water, and dipped in a solution of mercuric nitrate, freshly made by adding excess of nitric acid

to mercury. The copper wire on removal is coated black, but when rubbed with a cloth, a bright covering of mercury results.

Zinc, in the form of rods or plates, is used in many primary cells, and, owing to the expensive nature of chemically pure zinc, these rods and plates are generally made of the commercial metal. Such zinc, however, contains many impurities, which cause "local action," thereby interfering with the efficiency of the cell. This local action can be prevented by amalgamating the surface of the zinc with mercury. (Mercury is so expensive that many teachers omit the amalgamation process.)

The zinc should be thoroughly cleaned with sandpaper and any small pieces of the metal removed. This is followed by a washing in dilute caustic soda to remove any grease (about 2N strength of the soda is used). The soda is then washed off and the zinc is dipped in dilute sulphuric acid, where it remains until effervescence commences. It is then immediately taken out, washed with tap water, then with distilled water, and dried. Mercury is then rubbed over the surface with a hard brush or cloth, and since the fingers must not touch the metal, the cloth is fastened to the end of a glass rod or a piece of wood. Care must be taken to cover all the surface. Afterwards the zinc is left to drain in a dish to catch the spare mercury.

Very little mercury is required except in the case of the cylindrical plate of the bunsen cell. Such a plate must be placed in a suitable vessel with a little mercury. The vessel should then be rocked so that the mercury comes in contact with all the surface, which should then take on a bright colour. The plate must be further treated in parts, if necessary, with a cloth and more mercury as above.

Mercury which has been in contact with zinc must

not be returned to the mercury reservoir, since it is contaminated, but it should be stored separately and used for future amalgamations.

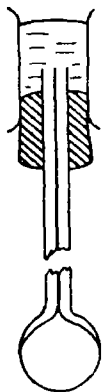
Amalgamated rods and plates should be inspected at intervals, and if any black spots have appeared, the zinc must be re-amalgamated in these places only. It is not advisable to re-amalgamate too frequently, since by doing so the zinc becomes rotten and brittle.

Ammeters.—The current used in electrical experiments rarely exceeds one ampère and usually ranges between 0.5 and 0.01 ampère. Hence ammeters with a range of from 0.01 to 1 ampère should be obtained. All test Instruments are provided with shunts and will give increased range if necessary. Only one such instrument is required as well as, possibly, a milliammeter with shunts.

Bulb Tubes. To Clean and Fill.—Such pieces of apparatus as weight thermometers and constant volume air thermometers, *i.e.* apparatus consisting of a bulb to which is sealed a capillary tube, may be cleaned by means of the chromic acid solution (see p. 38). This is best introduced into the bulb by heating the latter in a water-bath, or often the heat of the hand is sufficient, and then dipping the open end under the liquid. The heat drives out a little air and thus, when the vessel cools, some of the liquid is sucked in. The operation is repeated until sufficient liquid has been introduced (it is by no means necessary to fill the bulb), and the liquid is then swirled round. It is then expelled by holding the bulb upside down and heating it. The bulb is next similarly washed with distilled water and then with alcohol. It is finally heated and the alcohol vapour sucked out by the pump.

It is a little difficult to fill a thermometer tube in this manner with mercury, hence the following device

may be employed. The diagram is almost self-explanatory. Warm mercury is placed in the upper tube and the bulb is heated as before. When the bulb cools, the mercury is sucked into it. (If the mercury had not been heated, there would have been a risk of the cold mercury fracturing the hot glass.)



Unfilled thermometer tubes can be obtained from most dealers already provided with a funnel arrangement at the top. In such a case, warm mercury is placed in the top and the above process carried out. These unfilled thermometer tubes are very cheap and are very useful in showing the construction of a thermometer.

Calorimeters.—Calorimeters should be of “spun” copper or aluminium in one piece, since solder readily melts, is liable to leak, and has a different specific heat from copper. Moreover, the presence of the solder makes it impossible to determine accurately the water equivalent of the vessel by a simple weighing and calculation.

The most serviceable size for a calorimeter is 3 in. by 2 in. and some 3 in. by 1½ in. About two dozen of each size are ample for an ordinary laboratory, and good cheap ones provided with a holder for the thermometer can now be purchased. For elementary work it is not necessary to provide the elaborate double vessels. A simple copper calorimeter serves if this is placed on a large flat cork within a glass beaker. If desired, a layer of sheet asbestos, ½-in. thick, may be used to give better insulation. In all elementary work it is useless to provide apparatus more elaborate than the inaccurate working of young students warrants. One or two good calorimeters, as described by Glazebrook and Shaw (and

others), should be obtained for the advanced students and for demonstration purposes.

Large masses of metal should be used in specific heat determinations; the 100-gram masses are very serviceable.

Capillary Tubes.—Small glass capillary tubes are used in melting-point and in boiling-point determinations and in experiments on surface tension. For all of these tests it is essential that the inner surface be clean and dry. Hence a piece of glass tubing, about 6 mm. in diameter, or a test-tube, is cleaned with caustic soda and chromic acid followed by distilled water. It is then heated in the bunsen flame, being rotated the while, until it is soft. The tube should not be heated to redness. The tube is withdrawn and each end pulled until the diameter of the capillary is about 1 mm. The tube should not be drawn out whilst still in the flame. The capillary tube may be cut into suitable lengths and stored for use. The solid whose melting-point is to be determined may be introduced by melting it and allowing it to run in, or by poking it into the tube with a pin.

Cells.—The primary considerations governing the choice of a cell are the E.M.F. of the cell, its internal resistance and the steadiness of the current. In addition, there have to be considered its cost, its cleanliness in use, especially the absence of fumes, the trouble necessary to recharge the cell and its likelihood of deterioration, when not in use.

The characteristics of the various cells, and the methods of charging them, are given below.

The Bichromate Cell.—The solution is made by dissolving 100 grams of potassium bichromate crystals in a litre of water, and adding to this, when cold, 120 c.c. of concentrated sulphuric acid. The addition of the acid must be done gradually and with constant stirring in an earthenware jug or pneumatic trough.

The acid must not be added to the water in the glass cell, since much heat is liberated and the glass vessel may be broken. When the cell is not in use, the zinc plate should be raised out of the solution and clamped fast to the central rod. If this is not done, the zinc reacts with the excess acid present.

Where a battery of bichromate cells is used, the cells are often left exposed to the air, so that evaporation takes place. In time crystals of chrome alum separate out, which adhere firmly to the bottom of the vessel and are difficult to remove. Hence water should be added occasionally to such cells to make up for the loss due to evaporation. Since sodium chrome alum is much more soluble than potassium chrome alum, it is perhaps better to use sodium bichromate instead of potassium bichromate in such a cell. The same weight of either salt is required, since the molecular weights of the two salts are approximately the same, *i.e.* $\text{Na}_2\text{Cr}_2\text{O}_7 \cdot 2\text{H}_2\text{O} = 298$, $\text{K}_2\text{Cr}_2\text{O}_7$ (no water) = 294.

The bichromate cell has an E.M.F. of about 1.9 volts and a low internal resistance. It can be used for supplying a moderately strong current for a short time. In many laboratories only one or two bichromate cells are kept for use as models.

The Bunsen Cell.—The sulphuric acid used in this cell should be approximately three times normal; hence dilute the concentrated acid twelve times. Sufficient of it should be placed in the cell to keep its level higher than that of the nitric acid, so as to compensate for any diffusion. After each use the acid must be thrown away, since it contains some nitric acid which will have diffused through the pot. Concentrated nitric acid is used as the other solution; this acid should be poured out of the cell after use and stored for future occasions. It should be discarded when it becomes a deep greenish blue in colour.

Very few science masters make use of this type of cell, owing to the disagreeable fumes of oxides of nitrogen which are formed. Moreover, if any of the nitric acid is spilt, it attacks any metal with which it comes into contact and thus all delicate pieces of apparatus must be placed away from the cell. The cell should be set up in a fume cupboard, dismantled immediately after use and the acids treated as above. The porous pot should be placed in a vessel of water so that the zinc sulphate is washed out of the pores. If this is not done, the zinc sulphate will crystallize in the pores, causing the pot to crack. The zinc and carbon may also be stored in water.

The cell has an E.M.F. of about 1.9 volts; its internal resistance is small and so the cell is a suitable one for supplying a moderate current for about three hours where a slight variation in E.M.F. is of little importance.

One bunsen cell is sufficient, since it is rarely used except for demonstration.

The Daniell Cell.—The sulphuric acid is prepared by adding 80 c.c. of the concentrated acid to a litre of water; the copper sulphate solution is a saturated one made by dissolving about 400 grams of the crystals in a litre of water to which a few c.c.s of acid have been added to prevent the formation of the basic salt.

The E.M.F. is variable, usually in the neighbourhood of 1.14 to 1.07 volts, and is greatest when the copper sulphate is completely saturated and when no zinc sulphate has been formed. As the cell is working, the copper sulphate becomes used up and some zinc sulphate formed. The latter cannot of course be avoided, but the former can be remedied by placing crystals of copper sulphate on the perforated shelf, and this is usually done. Notwith-

standing this, the E.M.F. gradually falls in value, and therefore many prefer to use a saturated solution of zinc sulphate (50 grams per litre) in place of the sulphuric acid. If this is done, the E.M.F. is lower than when pure acid is used, being about 1.08 volts, but it has the advantage of remaining practically constant. A few small pieces of zinc, placed at the bottom of the zinc sulphate solution, decompose any copper sulphate which diffuses, forming zinc sulphate and copper.

Immediately before use it is best to short-circuit the cell (for ten minutes) by connecting the zinc and copper poles together by a short wire. This wire must be removed before the cell is used. After use the solutions are poured from the cell and stored in bottles for future use, since if the cell is left set up, the copper sulphate will diffuse into the zinc sulphate. The zinc plate should be washed clean after each use. The Daniell Cell is very useful, and a normal stock for an ordinary laboratory would be one dozen.

Gravity Daniell's Cell.—There are many varieties of this cell on the market and in all the types the porous pot is discarded. A saturated solution of copper sulphate is denser than one of zinc sulphate, and thus the two do not mix if carefully placed in one vessel (hence the name of the cell). Such cells, therefore, should not be shaken, and great care has to be exercised in moving them. For this reason they are not particularly suitable for school purposes. An ordinary Daniell's Cell is suitable for supplying a small current for a long time. It should not be left set up for more than two or three hours. Its internal resistance is very high in comparison with other cells of the same size. One great advantage this cell has for school use is that it can be short-circuited without causing any damage. No other cell can be so treated.

The Leclanché Cell.—Although a saturated solution of ammonium chloride is generally used in connection with this cell, owing to evaporation crystals of ammonium chloride are sometimes deposited on the zinc rod and react, forming the double zinc ammonium chloride. For this reason many prefer to use a solution not quite saturated. This cell is specially suitable for school work. It requires little attention, other than keeping the vent holes open by means of a pin, while it may be left set up for months without any decrease in the E.M.F. taking place. None the less it is advisable to remove the zinc after use.

It has an E.M.F. of approximately 1.5 volts, but this rapidly diminishes when the current is passing. It soon regains its former value, however, when the cell is left unused for a time.

The cell is suitable for producing small intermittent currents where polarization is of little importance, *e.g.* for bells and work with the Wheatstone's bridge.

About one dozen Leclanché Cells is a normal equipment.

Dry Cells.—These are not really dry, since moisture is necessary for the chemical action. But they contain no loose liquid, and so can be readily carried about and used in any position. They require no attention.

Dry cells should be stored in a cool place, or the moisture may evaporate and cause an increase in the internal resistance. However these are stored, a gradual lowering of the E.M.F. and an increase in the internal resistance takes place; hence the life of the cell, even when not used, is rarely more than a year or so. Unfortunately, a used-up cell is of little value; a few manufacturers will repurchase such cells, but sometimes the used cell may be taken to pieces for teaching purposes.

Secondary Cells or Accumulators.—Nowadays all

accumulators bear a label of printed instructions, and these should be carried out carefully. The sulphuric acid used has a specific gravity of 1.25 and is best made up by the use of a hydrometer. The level of the acid should be maintained about $\frac{1}{4}$ -in. above the plates, and if any is spilt, it should be replaced immediately, while water which escapes by evaporation should also be replaced. A special hydrometer can be purchased, by means of which 20 c.c. can be withdrawn from the accumulator, its specific gravity noted and the liquid returned.

The voltage of the accumulator should be noted at intervals, and when it has dropped below 1.9 volts, the accumulator needs recharging. When the accumulator is freshly charged, it has a voltage of approximately 2 volts, which remains at this value until the cell is *nearly* discharged. Then the voltage drops very quickly to about 1.8 volts. Generally the voltage should not be allowed to fall to this low value.

Owing to the acid attacking the plates, an accumulator left charged, even if not in use, loses its charge in time. The terminals should be kept dry and all connections firmly made. If more than one accumulator is being used, care must be taken to avoid short-circuiting; the positive and negative poles of the same accumulator should never be connected directly by means of a wire only, even for a short time.

One dozen accumulators with a voltage of 2 volts and an ampère hour capacity of 60 are required.

Coloured Liquid for experiments in Hydrostatics and Heat.—Dissolve 1 gram of fluorescein in 100 c.c. of methylated spirits. Add a few drops only of this solution to about 1 litre of water.

Compasses.—The cheap varieties are almost useless for school work, especially for plotting fields of magnetic force. The probable cost of a compass suitable for such a purpose is about 5s.

Connecting Wires.—Stout copper insulated wire should be purchased for making connections. It should be about No. 20 Standard Wire Gauge (S.W.G.). This wire can conduct a current of about 5 ampères without being overheated and it has a low resistance. If the wire is thicker, certain pieces of apparatus may be upset when the wire is accidentally moved.

Dutch Metal.—Dutch metal can be cut into pieces suitable for an electroscope by placing it between folds of writing paper and cutting both metal and paper at the same time.

Dutch metal should be kept well wrapped up, especially if there is a probability of any fumes being present.

Electrostatics.—The insulating material, as well as the rubbers used in experiments on electrostatics, must be dry. If either are moist the rods cannot be electrified. Hence it is advisable to place the rods, especially glass rods, as well as the silk or fur rubbers, in a warm place immediately before use (over the radiator is a suitable place). Care is of course necessary when attempting to dry a rod of sealing wax in this manner.

Glass retains moisture to a greater extent than ebonite, and therefore, when choice can be exercised in the selection of an insulating material for the handle of a conducting rod, etc., the handle should be of ebonite. Where glass handles are provided, they may be coated with a shellac varnish since this does not retain moisture to any great extent.

When determining the dielectric constant of some dielectric such as glass or ebonite by means of the plate condenser, it is often found that some charge has been retained by the plate from some previous experiment. The charge can be dispersed by just passing the bunsen flame over the plate momentarily. Care must be taken not to allow the flame to remain

at one spot too long, or the glass, etc., may be cracked. Suitable quantities are about one and a half dozen vulcanite or ebonite rods, half a dozen glass rods and half a dozen blocks of paraffin wax, 6 in. \times 3 in. \times 2 in.

Experiments in Electricity and Magnetism.—

For success in such experiments certain precautions are necessary. It has been mentioned previously that the position of the physical laboratory should be such that there are no large masses of iron in the neighbourhood. Similarly, most of the experiments should be conducted away from ironwork of any description, and for some it is even advisable to remove watches from the experimenter's pockets.

Wrong connections, short-circuiting, and too strong a current may ruin many delicate pieces of apparatus, and thus the teacher must make it a general rule to inspect all apparatus before a current is passed. Short-circuiting occasionally occurs when the connecting wires are not insulated in parts; hence all such wires should be properly insulated and any covering which has been removed replaced. Special binding tape can be purchased.

The wires should be arranged in a tidy manner. It is usual either to twist the wires together, or to make a coil of the single wire by wrapping it round a pencil and then removing it. It should be possible to trace the connection made by any wire by a single glance. This of course cannot be done when the wire is allowed to stray all over the bench. All connections should be securely made; merely twisting the ends together is not sufficient for accurate work, but a metal connector should be used. All connections should be as free as possible from dirt and grease and should be tightly made. Sand-paper, or emery cloth, is very handy for touching up terminals and wire ends, etc.

All the apparatus should be stored in a dry place and kept dry, and where there is any unwanted residual charge this should be dispersed (see Electrostatics, p. 89, and Methods of Demagnetizing, p. 94).

Hydrometers.—Hydrometers are very useful instruments for determining quickly the specific gravity of a liquid when only a fairly accurate value is required. But to obtain a reading, even of moderate accuracy, the hydrometer must be used properly. There is a capillary attraction between the stem of the instrument and the liquid, and unless this is got rid of, the reading will be a few degrees higher than the true value of the specific gravity. Hence if the stem of the hydrometer is at all greasy, it must be washed first with a caustic soda solution and then with water. Even if this is not done, the stem should be wetted with the liquid whose specific gravity is to be found. It should then be thrust well into the liquid, so that the latter reaches the top mark of the instrument, and then allowed to come to rest for some seconds before reading it. Two or more readings should be taken until two consecutive values agree.

Three types of hydrometers are in ordinary use—the common hydrometer, so graduated that the specific gravity can be read immediately, the Twaddell's Hydrometer, and Baumé's Hydrometer. The first is the one generally used in a school laboratory. Twaddell's Hydrometer is much used in commerce, and advanced students, at least, should become acquainted with it. The zero of the scale is determined by sinking the instrument in water at 4°C. , and therefore 0°Tw. equals a specific gravity of 1. The top mark, 200°Tw. represents a specific gravity of 2, and the scale is divided into single degrees.

Hence 1°Tw. represents a specific gravity of $1 + \frac{1}{200} = 1.005$. Degrees Twaddell can therefore

be converted to specific gravity values by the formula $1 + x/200$ or

$$\text{Specific gravity} = 1 + \frac{5x^\circ \text{ Tw.}}{1000}$$

where x° Tw. is the reading of the hydrometer.

Baumé's Hydrometer is much used in America and on the Continent. It is constructed so that 0° Bé. equals a specific gravity of 1. For liquids heavier than water, the Rational Baumé's scale is usually employed. The instrument is so graduated that when in concentrated sulphuric acid, of specific gravity 1.842, the hydrometer reads 66° Bé. The conversion formula for liquids heavier than water is $\frac{144.3}{144.3 - n}$.

For liquids lighter than water a different scale is used. Zero is the specific gravity of a 10 per cent. solution of common salt, and the specific gravity of water, at 15° C., is represented as 10° Bé. The conversion factor for such liquids is $\frac{146}{136 + n}$, where n in both cases is $^\circ$ Bé.

A nest of Twaddell's Hydrometers, one or two Baumé's Hydrometers, and one or two Nicholson's Hydrometers, with a deep-bottomed cup, are ample.

Iron Filings.—Iron filings find their chief use in the physical laboratory in the plotting of lines of force. For such a purpose the iron filings should be put through a sieve (a piece of wire gauze serves) and only the small particles used.

Permanent maps may be made by the use of waxed paper (see p. 99). The filings should be placed on the waxed side of the paper with the magnets underneath. When the filings have taken up their proper positions, a bunsen flame is passed over the paper. The wax then melts and, on cooling, solidifies with

the iron filings embedded in it. Such maps are somewhat untidy, since the iron filings occasionally rust. In place of the waxed paper a piece of photographic paper may be used. As before, the iron filings are sprinkled on to the sensitive paper, this operation being done in a dark place and the paper then carried into the sunlight and left there until it attains the proper colour. It is fixed in the usual manner, *i.e.* by means of a hypo solution.

Lenses.—Lenses are most conveniently stored in an ordinary spectacle trial case, as used by opticians. There is then little danger of the lenses becoming scratched through rubbing against each other. Each lens should be given a characteristic number, which may be etched on the glass, or written on with Duro ink in some place not too conspicuous. An entry may then be made in the laboratory log-book of the constants of each lens.

Care is needed when cleaning a lens that the surface is not scratched, and for ordinary purposes, a soft silk handkerchief is perhaps the best; the cloths supplied by opticians for spectacles will also serve. Another method is given under Optical Glass, p. 95.

Compound lenses are usually cemented together by Canada balsam, and since this substance is soluble in turpentine, ether, benzene and many other organic liquids, such substances should not be used to clean the lenses. Naturally a compound lens should not be immersed in the liquids named.

Lenses can be maintained in an upright position, or any other, by means of plasticine, and for most school purposes this serves instead of the elaborate lens-holders now on the market.

Magnets.—In order that bar magnets should retain their magnetism, they are stored in boxes along with “keepers.” Each magnet is separated

from its neighbour by means of a small fillet of wood and is paired with another so that opposite poles of either magnet face the same end of the box. Thus the North pole of one is joined to the South pole of another by means of the keeper, which is a small bar of soft iron. A keeper is placed at each end of every magnet. If for some reason this arrangement cannot be carried out, the magnets may be stored end on, with the North pole of one magnet touching the South pole of the other. Horseshoe magnets are stored with one keeper touching both poles.

Magnets should not be exposed to rough treatment, for this destroys the magnetism, especially that of the new chrome nickel magnets. Such magnets are made in cylindrical shapes as well as in bars, and are much more powerful than steel magnets of the same size. Keepers are not necessary for these cylindrical magnets, for if placed together in pairs with opposite poles facing the same direction, they will attract each other and so remain together.

Knitting needles, or pieces of watch spring, can be demagnetized by heating them to redness and plunging them suddenly into cold water. This, besides destroying the magnetism, tempers the steel, so making it hard, the condition required for magnetization.

Mirrors.—The best mirrors are those silvered on the front surface, since then the thickness of the glass need not be taken into account during an experiment. Plane mirrors can be made if desired, by silvering microscopic slides; but since such slides have not always a level surface, mirrors so made are not suitable for accurate work. Convex and concave mirrors may be made by silvering the front surface of a suitable lens.

Nothing but disappointment can be obtained from the use of the cheap concave and convex mirrors, for

the images formed are generally blurred when the object is not close to the mirror.

It is useful to mark each mirror with a distinguishing number and to enter this number in the laboratory log-book along with the focal length of the mirror.

Large pins—blanket pins—may be purchased and are recommended for the usual experiments on the reflection and refraction of light.

Nomenclature of Magnetic Poles.—Confusion often exists owing to the loose terminology employed in defining the poles of a magnet. Amongst others, the following names have been used, the one indicating that pole which points to the geographical North being given first :

North Seeking pole.	South Seeking pole.
North pole.	South pole.
True South pole.	True North pole.
Positive pole.	Negative pole.
Marked end.	Unmarked end.
Red end.	Blue end.

Optical Glass.—Optical glass differs from ordinary glass in that it has been rendered as homogeneous as possible during its manufacture. This is done by constantly stirring the molten glass.

Special care is required when cleaning such glass if scratching is to be avoided. For ordinary purposes, it is sufficient to wash the glass thoroughly in hot water and soap, using pure Castile soap or sodium oleate, and a clean soft cloth or swab of cotton wool. The soap should then be washed off with methylated spirits and the glass rinsed with distilled water. If the water wets the surface uniformly, the cleaning has been done satisfactorily; if not, the operation must be repeated. The glass should then be dried with a chamois leather, specially

kept for this purpose, and it must not be touched by the fingers.

If the glass is in a very dirty condition, it may be washed first in the dilute chromic acid solution (see p. 38) followed by a solution of potash and then water. Glass should always be washed by the latter method before attempting to silver its surface. A final washing with a dilute solution of stannous chloride, followed by water, is said to make the deposition of the silver easier.

Pendulum Bob.—For all simple experiments a pendulum can be made readily by fastening a small piece of lead, or a small ball bearing, to a piece of thread by means of sealing wax. Specially cast lead bobs with copper shanks may be purchased. The other end of the thread is secured to the end of a rod or other support, also by means of sealing wax, with the wax as low as possible so that only the thread below the rod vibrates along with the bob.

One compound pendulum and about 2 dozen pendulum bobs is a normal equipment.

Porous Pots.—Before a porous pot is used in an experiment, or in the fitting up a cell, it should be examined to ensure that it is not cracked. This is done by drying the pot in a suitable place and then filling it with water. The water diffuses through the pores of the cell gradually and the time taken to do this is noted. If the pot is cracked, moisture will appear on the outside almost as soon as the water is placed within, and the pot is useless. If the pot is in good condition, about four minutes should elapse before any water diffuses through.

Porous pots are apt to crack if stored in a dry place. They should, therefore, be stored completely immersed in water.

Pots which are to be used in cells require special treatment, since many solutions, *e.g.* zinc sulphate

and certain acids, creep up the sides of the pot and often crystallize in the pores, so causing breakage. To prevent this creeping, the pot is usually held vertically upside-down to about half an inch deep in a bath of molten paraffin wax. The wax should not be too hot; it must be just molten. The wax solidifies on cooling and so prevents creeping.

Rain Gauges.—A few physics masters have to be responsible for keeping an account of the rainfall of the district. Rain gauges should be placed in an open space away from any buildings, walls, etc., that may interfere with the collection of the water. The gauge should be as far away from the foot of the wall as the building is high. It should be firmly fixed so that the top is level, and emptied once a day unless there has been a particularly heavy fall of rain, when it may be emptied immediately.

Resistance Boxes.—A dirty resistance box cannot be efficient since the electric current will be conducted along the dirt from one piece of brass to another. Thus, any film of dirt which does settle on the ebonite should be cleaned off with a cloth moistened in paraffin oil. To make this cleaning easier, the brass pieces are often cut away at the bottom of each plug hole so that a cloth may be inserted and pulled to and fro.

Plugs should not be allowed to become dirty or greasy, and must be occasionally wiped with a clean dry cloth. Any method of cleaning which takes away metal cannot be employed, since the plug must fit tightly.

The plugs, although not tapped, should be inserted with a screwing motion and a slight downward pressure. This ensures a tighter and better contact, and to help to attain this the plugs are made conical. The reverse process is necessary when removing a plug. Plugs should be loosened when the box is stored, to relieve the strain.

The wires of which the coils are made are of managanin or Constantin, or of German silver in the cheaper boxes. These wires are covered with paraffin wax, and therefore a large current should not be passed through the box or the heat generated may be sufficient to melt the wax.

Great care is necessary when using a box in connection with a Grove or Bunsen Cell, owing to the fumes produced by such cells.

About half a dozen resistance boxes, one Post Office box and a few (three) rheostats will be sufficient.

Smoked Glass.—The smoked glass required for the falling plate experiment, etc., can be made by using any heavy hydrocarbon, such as turpentine, camphor or benzene. The substance is placed in a vessel and set on fire, or a piece of cotton wool may be soaked in the liquid and lighted. The glass should be moved about in the smoke so that a uniform layer is deposited on it. In an emergency a candle-flame may be used instead of these hydrocarbons.

In place of the glass a piece of stiff paper, *e.g.* cartridge paper, may be employed, and this, after the experiment, may be coated with a layer of paper varnish and then pasted in the student's notebook without any fear of the latter becoming soiled.

Soap Solutions.

Searle's Recipe for Surface Tension Work.—Dissolve 18.75 grams of sodium oleate in 750 c.c. of distilled water, *without warming*, and to it add 250 c.c. of Price's glycerine. Shake the solution vigorously and leave it in a dark place for a week to settle, with the bottle stoppered. Siphon off the clear liquid (a soap solution cannot be filtered) and add one or two drops of strong ammonia solution. The solution improves on standing, provided the bottle is well stoppered and placed in a dark cupboard.

Soap Solution for Bubbles, etc.—This is prepared by the above method by dissolving 4 grams of Castile soap in 80 c.c. of water and adding 20 c.c. of glycerine. Such a solution keeps for a few weeks.

Voltameter Solutions.

The Copper Voltameter.—Dissolve 150 grams of copper sulphate crystals in a litre of water and to it add gradually 25 c.c. of concentrated sulphuric acid, to prevent the formation of the basic salt. About 60 c.c. of alcohol (rectified spirits) may be added, since this tends to prevent the formation of secondary products, alcohol being readily oxidized. This copper sulphate solution should not be used in the Daniell Cell and then in the voltameter, for while in the cell it is likely to become contaminated with zinc sulphate.

The copper cathode can be cleaned by fine emery cloth, followed by dipping the plate for a moment in dilute caustic soda and then in acid. The deposited copper should be washed with distilled water, followed by alcohol, and then dried.

Water Voltameter.—The water should be acidified with concentrated sulphuric acid—about 3 c.c. of acid to every 100 c.c. water.

Waxed Paper.—Waxed paper is very serviceable as an insulator in the preparation of condensers and for mapping out magnetic fields with iron filings.

Solid paraffin wax is heated in a flat tin over a water-bath and is ready for use just before it smokes. If wax is heated much above its melting-point, it loses some of its insulating properties. White unglazed paper, free from holes, is dipped into the wax and any air bubbles dispersed. It is then hung up until the wax has solidified.

Wimshurst Machine.—Before attempting any work with this or similar machines, the machine should be cleaned from dust, especially the metallic

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fittings and the insulating supports, a piece of soft dry warm silk being used. This also dries these parts. The brushes should be inspected to see that they are touching the plates.

On starting the machine, the handle should be turned slowly and the movement of the plates examined; they should rotate in opposite directions. Next the knobs should be placed very near each other, but without touching, and the handle turned until a spark is produced. If sparks do not appear after a few turns, a negatively charged ebonite rod should be held near the plate opposite one of the charging brushes and the handle turned again.

One Wimshurst or other electrical machine is sufficient.

CHAPTER V

THE BIOLOGICAL LABORATORY

ALTHOUGH Nature Study is taught in nearly every school in this country, its parent studies, botany and zoology, are not in such a favoured position as chemistry and physics, and only a few schools possess laboratories specially set aside for biological work. None the less, the teacher of biology has his own routine duties to do in the laboratory and some of these will now be reviewed.

The Preparation of Reagents and Stains

It is not possible within the compass of this small book to deal with the methods of using the various reagents mentioned. Most text-books, however, state how this should be done and special reference may be made to two books to which the author is indebted, namely, *Methods of Plant Histology* by C. J. Chamberlain, and *The Microtome's Vade Mecum* by A. B. Lee.

Unless otherwise stated, an x per cent. solution is made by dissolving x grams of the solid in 100 c.c. of the solvent named and no special directions are necessary.

Acetic Acid.—For remarks on Glacial Acetic Acid see p. 54. A 1 per cent. solution, which is the strength usually required, is prepared by adding 1 c.c. not 1 gram, of glacial acetic acid, measured by means of a small pipette, to 100 c.c. of water.

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Acid Fuchsin.—A 1 per cent. solution in water is required. A little camphor may be added to this solution if it is necessary to preserve it.

Agar-Agar.—Agar-agar is a gelatinous substance obtained from certain algae. It swells considerably when placed in water, and in so doing it absorbs about 200 times its own weight of the water, the product being a jelly. This jelly, when mixed with a nutrient solution, forms a good medium for culture work. Agar-agar is purchased in its solid state.

Alcohol.—Absolute alcohol should be stored in a well-stoppered bottle which contains a lump of quicklime, or some anhydrous copper sulphate. This alcohol is very hygroscopic and the quicklime is placed in the bottle to combine with any water the alcohol may absorb.

Absolute alcohol is somewhat expensive, even when bought duty free, and therefore Ranvier's method may be employed to obtain an alcohol which is absolute enough for most school purposes. In this method anhydrous copper sulphate, prepared by heating powdered blue vitriol crystals in an oven to 210°C ., is added to rectified spirits and left there for a few days. When this copper sulphate has become hydrated, a fresh supply is added and the process repeated until the anhydrous sulphate is no longer turned blue when added to the alcohol.

Absolute alcohol which has been used once should not be replaced in the storage bottle, for it is no longer absolute. Instead it should be filtered if necessary, *e.g.* if it has been in contact with small spores, and placed in a separate bottle. When sufficient has been collected, the specific gravity of it should be determined by means of the hydrometer, its strength calculated and the alcohol diluted and used for other purposes.

Industrial methylated spirits (see p. 123) may be

used in place of ordinary alcohol, except of course where absolute alcohol is specified. The spirits may be regarded as a 95 per cent. solution and from it solutions of other strengths can be prepared, *e.g.* a 70 per cent. solution, the usual preservative, may be made by taking 70 c.c. of the spirit and adding to it 25 c.c. of water. More generally stated, if an x per cent. alcoholic solution is required, then x c.c. of the spirit should be added to $(95 - x)$ c.c. of water. There is, however, a considerable shrinkage when alcohol and water are mixed, and hence the required volume of each liquid should be measured in a separate measuring cylinder.

Material preserved in 70 per cent. alcohol soon becomes brittle. It may be softened before use by placing it overnight in a solution of alcohol and glycerine, present in equal proportions, and leaving it there until next day.

Aniline Chloride or Sulphate.—An aqueous saturated solution of either of these reagents, to which has been added the corresponding acid, is used.

Bismarck Brown.—A 2 per cent. solution in 70 per cent. alcohol of this stain is usually employed.

Borax Carmine.—Dissolve 4 grams of borax in 100 c.c. of water and to it add 3 grams of carmine. Heat the mixture gently until all the carmine has dissolved and then add 100 c.c. of 70 per cent. alcohol and filter. If any precipitate forms on standing, it should be filtered off.

Bouin's Fluid.—This is prepared by taking 25 c.c. of 40 per cent. formalin, 75 c.c. of a saturated aqueous solution of picric acid and 5 c.c. of glacial acetic acid and mixing them together.

Canada Balsam.—Canada Balsam is a pale yellow, viscous, resinous substance, soluble in benzene, toluene and xylene (xylol). For biological work the

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solid is usually dissolved in xylol, and generally a solution in this reagent is purchased. It is best stoppered in a capped bottle such as may be purchased from most of the dealers; such a bottle prevents excessive evaporation. Occasionally the solution is too thin for some particular work, and when this is the case, the stopper of the bottle may be left out, so allowing some of the xylol to evaporate. When this is done, the bottle must be placed in such a place that contamination through fumes and dust in the atmosphere is avoided. If the balsam is too thick, it may be thinned by the addition of more xylol.

Xylol and water are non-miscible and thus, when a drop of water is added to xylol, a cloudy solution results. It is because of this that all material has to be thoroughly dehydrated before being mounted in Canada Balsam.

Chloral Hydrate.—A 16 per cent. aqueous solution is required. For many purposes it is necessary to dissolve iodine in this reagent.

Chrom-Acetic Acid.—The two reagents, chromic acid and acetic acid, are used in various proportions for different purposes, and hence it is convenient to prepare stock solutions of each and mix them in the required proportions for each particular experiment. One of these stock solutions contains 10 grams of chromic acid crystals per litre; the other is a 1 per cent. solution of acetic acid. (Chromic acid crystals are very hygroscopic and hence require careful storage.) In addition to these two stock solutions, a bottle of glacial acetic acid is required.

For most purposes a 1 per cent. solution is used, and this is prepared by adding 1 c.c. of glacial acetic acid to 100 c.c. of the 1 per cent. chromic acid solution. When a solution containing less than 1 per cent. of acetic acid is required, the 1 per cent. acetic acid solution is used in its preparation. Obviously

the supply of chromic acid solution required is much greater than that of acetic acid.

Cobalt Paper.—Cobalt papers may be prepared by soaking filter papers in an approximately 5 per cent. solution of cobalt chloride, after which they are dried until blue. They should be stored in a well-stoppered bottle, or in a desiccator, and, if necessary, dried just before use.

Corrosive Sublimate.—See Mercuric Chloride, p. 107.

Cuprammonium Sulphate.—This is prepared by adding ammonium hydroxide to a solution of copper sulphate until the precipitate which at first forms is just re-dissolved. A deep blue solution should result. This is best prepared when it is required, but it may be stored for a short time in a dark bottle.

Delafield's Hæmatoxylin.—A solution of this hæmatoxylin takes a considerable time to prepare, and the science-master will usually purchase it ready made. Its constituents are hæmatoxylin, absolute alcohol, ammonium alum, glycerin and methyl alcohol. The substance improves on keeping in a well-stoppered bottle, and, if necessary, it may be diluted with water.

Eau de Javelle.—This name is applied to a solution of potassium hypochlorite, which may be made from bleaching powder and potassium carbonate. 20 grams of the bleaching powder are ground with water in the mortar to the consistency of cream and the solution made up to 100 c.c. with water. Approximately 25 grams of potassium carbonate are dissolved in 100 c.c. of water and some 80 c.c. of this added to the previous solution, which is then filtered. More of the potassium carbonate solution is added, drop by drop, to the filtrate until no precipitate of calcium carbonate is formed on its addition.

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The solution is filtered and stored in a dark bottle in a cool place.

Eosin.—A 1 per cent. solution, either in water or in 70 per cent. alcohol, is required. The alcoholic solution is used when the material to be stained has been taken from alcohol.

Fehling's Solution.—See p. 62.

Formalin.—Formalin is the trade-name for a 40 per cent. solution of formaldehyde, and its chief use in biology is for preservation purposes. An x per cent. solution is made by taking x c.c. of the formalin and diluting it to 100 c.c. with water. It should be noted that this is an x per cent. solution of *formalin* and not of formaldehyde, the *actual amount* of the latter present being of course two-fifths of x .

A solution of formaldehyde decomposes on standing, with the formation of formic acid; but since formic acid is not detrimental to the preservation of many organisms, it is not always necessary to remove it. It may, however, be neutralized by the addition of a little sodium bicarbonate. Some people prefer to distil the solution after such an addition; others keep the bicarbonate in a small bag placed in the formalin.

Formaldehyde vapour attacks the eyes and should therefore be handled with care, and any vessel containing it should be perfectly sealed, owing to the volatile nature of the substance. Plants preserved in it do not retain their green colour; indeed, other vegetable colours are affected by this substance.

Formalin Alcohol.—This may be used as a preservative and is prepared by adding from 2 to 6 c.c. of formalin to 100 c.c. of 70 per cent. alcohol.

Gentian Violet.—A 1 per cent. solution in water is used. A 1 per cent. solution in 20 per cent. alcohol, to which have been added a few drops of aniline oil, may be substituted.

Glycerin (see p. 63).—There are many varieties of glycerin jelly on the market and all of them contain, besides glycerin, some gelatine; many of them contain in addition, egg albumen, chloroform or carbolic acid. There is little to choose between the different varieties.

Gold Size.—Gold size should be stored in a well-stoppered bottle, with a small camel-hair brush in the cork. It may be thinned with turpentine, and if the mixture is too thin, some of the turpentine should be allowed to evaporate.

Iodine.—A dilute solution of iodine is prepared by dissolving about 6 grams of potassium iodide in 100 c.c. of water and then adding to it approximately 1 gram of iodine. The solution may be diluted with water.

Iodine Green.—A 1 per cent. solution in 70 per cent. alcohol is usually used.

Lime Water.—See p. 60.

Mercuric Chloride (see also p. 65).—Mercuric chloride is not very soluble in water and a 1 per cent. solution is used as an antiseptic, while a saturated aqueous solution is used as a fixative. Mercuric chloride reacts with metals; hence metallic instruments, needles, scalpels, may not be placed in it; wooden scalpels or needles must be employed instead.

Methyl Green.—A 1 per cent. aqueous solution may be used, or a 1 per cent. solution in a 1 per cent. acetic acid solution.

Millon's Reagent.—Millon's reagent is prepared by dissolving mercury in its own weight of cold concentrated nitric acid (specific gravity 1.42). This should be done in the fume cupboard, and then an equal volume of water added. If a precipitate forms on standing, it should be filtered off. Millon's reagent contains mercurous and mercuric nitrates

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(and probably some free nitrous and nitric acid). It is usually purchased ready-made.

Oil of Cloves.—Oil of cloves darkens with age and also on exposure to air and light. It should, therefore, be stored in a dark, well-stoppered bottle.

Osmic Acid.—Osmic acid is a very expensive substance and is sold in sealed glass tubes. A very dilute solution only is used, generally 1 per cent., and it is usually most conveniently purchased ready-made. It should be stored in a well-stoppered dark bottle and be well protected from dust and organic matter. Osmic acid gives off a vapour which attacks the eyes and should therefore be used cautiously.

Osmosis, Solutions for.—Suitable solutions for demonstrating osmosis may be prepared by dissolving either 50 grams of common salt, or 150 grams of cane-sugar, in a litre of water.

Paraffin Wax.—Two varieties of wax are required—a soft wax with a melting-point between 42° and 46° C. and a hard wax with a melting-point of approximately 54° C. The variety required should be specified when ordering. The wax should be melted in a paraffin oven, or on a water-bath, and heated until it just begins to smoke. If the containing vessel on the watch glass is smeared with glycerin before the addition of the wax, the latter will slide off easily when solidified.

Phloroglucin.—A 5 per cent. aqueous solution, or a 5 per cent. solution in 70 per cent. alcohol, is commonly used. This should be acidified with hydrochloric acid. When purchased, this reagent is generally without the acid.

Picric Acid.—Picric acid is highly explosive when dry, but is harmless when moist. The solid should therefore be kept damp during storage. A 1 per cent. solution in water, or in 70 per cent. alcohol, is used.

Picro Carmine.—A 1 per cent. aqueous solution should be purchased.

Potassium Hydroxide (see p. 68).—Solutions of different strengths are required and are prepared by dissolving the requisite amount of the solid in water.

Pyrogallate of Potash.—Dissolve 5 grams of pyrogallie acid ("pyro") in 100 c.c. of water. In another 100 c.c. of water dissolve 25 grams of potassium hydroxide. Mix equal volumes of the two solutions immediately before use.

Safranin.—A 1 per cent. solution in 50 per cent. alcohol is required.

Sudan III.—This stain is best purchased from the dealers.

Water Culture Solution.—A suitable solution for water culture work may be prepared by dissolving in 1 litre of distilled water 1 gram of potassium nitrate, 0.5 gram of sodium chloride, 0.5 gram of magnesium sulphate, and 0.5 gram of calcium nitrate. To this is added either a rusty nail, or one or two drops of a ferric chloride solution.

The Care and Cleanliness of Apparatus

The Aquarium.—The subject of aquaria is too large a one to be discussed here, for unless very great care is taken, there is likely to be much cruelty and mismanagement. Hence any teacher who intends keeping animals in captivity should first of all make himself thoroughly acquainted with their habits by reading some such books as *The Book of Aquarium* by Bateman and Bennet; *Freshwater Aquarium* by Bateman; Furneaux's *Life in Ponds and Streams*, or Samuel's *Amateur Aquarium*. Bateman's book on *The Vivarium* may also be of interest.

Cover-Glasses.—Cover-glasses are made of three thicknesses, and for most school work the No. 2 grade is most satisfactory. It may be mentioned

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that the object-glass of the microscope is made for use with a thin cover-glass, and that for high-power work the thinner the cover-glass the better. Although the thicker glasses are cheaper per ounce, there are more of the thinner ones to the ounce and therefore there is little difference in the price of each cover-glass.

The teacher's chief care is to prevent breakages, which usually arise through careless storage, and to have the dirty glasses cleaned. The latter may be done by leaving them overnight in the chromic acid solution (see p. 38), next soaking them in water and afterwards washing them in alcohol. They should then be dried and polished, by rubbing them on a piece of chamois leather.

The School Garden.—Detailed information on the formation and management of school gardens is to be found in the Board of Education Pamphlet No. 41 (*Report on Botanical Gardens*, by L. J. Clarke), price 2s. from H.M. Stationery Office.

Glass Slips.—Glass slips are made of a standard size, *i.e.* 3 in. by 1 in., and are approximately 1 to $1\frac{1}{2}$ mm. thick.

It is usually advisable to clean new slips by means of a paste of prepared chalk and water, after which they should be placed in water, allowed to drain dry and finally polished with a cloth. Slides which have been used may be treated similarly and, if necessary, they should be rubbed with a cloth moistened with xylol, or with alcohol, before the above treatment.

The Herbarium.—One of the main scientific reasons why flowers and plants were first collected and preserved in herbaria was that specimens growing in foreign parts, etc., could be brought to the laboratory for identification. Herbaria were not intended to be used in a systematic study of plants, for obviously a dried plant differs very much from a living

one. Besides, the study of the environment is frequently a great help. Therefore the chief reason in encouraging a student to form a herbarium is not so much that he will have at hand a supply of plants from which he can study botany, but that the formation of a herbarium gratifies the "collecting instinct" and often leads to further study. Moreover, the endeavour to name a plant often involves a close examination of it, and thus, whenever a herbarium is being formed, the student should be made to name every plant himself, using a *Flora*. The educational value is lost when the teacher is at hand to name every plant the student brings. All he has to do is to ensure that the classification is done properly. Mere mechanical collection must be seriously discouraged and the destruction of too many plants prohibited. Moreover, a school herbarium should contain the commoner plants rather than the rarer ones.

There is a certain amount of skill required in collecting plants for preservation. It is not enough to collect the flower only, but the fruit, leaves, and often the root, must also be gathered, especially when there is some characteristic feature of any of these parts. Occasionally it is possible to collect a stem bearing both flower and seeds, but more often the seeds have to be collected from a different specimen, often at a different time. When this is so, it is advisable to choose a stem bearing leaves as well as the fruit, to avoid mistakes in identification. The date, locality, and the environment of the plant should be recorded at the time of collection and the plants placed in a vasculum, or in a tin box, or wrapped in waxed paper.

The first process in preservation consists in drying and pressing the plant. The latter should be arranged so as to show the most characteristic features and

placed between sheets of bibulous paper specially purchased for this purpose. Many kinds of white blotting paper are unsuitable, since they contain some of the bleaching agent used during the manufacture of the paper, which affects the specimen. About four sheets of this paper should be used and the whole placed between two boards, on which weights may be placed. At first only a gentle pressure is needed, but as the plant becomes dry, the pressure should be increased. The quicker the drying the better, and hence the drying press should be placed in a current of air in a warm place. To ensure this quickness in drying, a wire frame may be used in place of the boards to support the bibulous paper and plant. This frame is constructed somewhat after the manner of a trousers press, *i.e.* it has screws whereby pressure may be exerted. The wire frame is also hung in a warm place.

When the plant has dried, it should be brushed on both sides with a dilute solution of mercuric chloride ($\frac{1}{2}$ gram per 100 c.c. of methylated spirit). This will prevent the growth of fungi, etc., and the plant is then ready for mounting.

Fairly large mounting sheets should be chosen, *e.g.* demy size, and, since cartridge paper attracts moisture, some other kind of paper should be used, *e.g.* ordinary drawing paper or, of course, the paper sold specially for this purpose. There are many ways of fastening the specimen to the paper; for example, the plant may be glued fast to the paper. But in all cases where gum or glue is used, care must be taken that the adhesive has been treated to prevent the growth of moulds. Many of the dealers sell a specially prepared glue for this purpose, or one may be prepared by mixing equal quantities of gum arabic and tragacanth, to which has been added a little mercuric chloride. Other ways of fixing the plant to the paper

may be mentioned, *e.g.* ordinary stitching with thread, the use of gummed strips of paper, or the use of strong slips of paper inserted in holes and fastened to the back of the mount. Often it is necessary to use more than one of these methods; for example, thick stems are best secured by stitches, or by gumming the whole length of the stem; leaves with a waxy surface need stitching through the centre; small petals are firmly secured by a drop of gum, and so on.

Seeds, small fruits, as well as a section of the root, may be preserved in small envelopes fastened to one corner of the sheet. Some of the roots are much too bulky to be placed in the ordinary herbarium; in that case a separate collection of roots may be made and indexed, so that reference is easy.

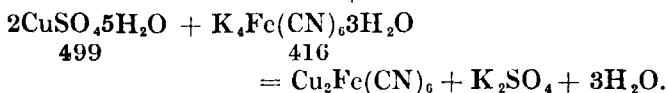
Each sheet should be labelled, the right-hand bottom corner being usually reserved for this purpose. The label should include the name of the plant, its species, where found and the date (with, possibly, its number in the London Catalogue). The appearance of the sheet is much enhanced if proper labels are used; these can be obtained from most of the dealers. Any special point of interest in the specimen should be noted on the sheet, possibly by means of a small diagram indicating the feature concerned.

The sheets should then be arranged in some systematic order. The alphabetical order of the name of each natural order seems the simplest, for then a person with a little knowledge of botany can see if a sheet is out of place. Finally, the herbarium should be stored in a large drawer containing a few balls of naphthalene to prevent insect attack. The naphthalene will require renewing periodically.

Membranes, Semi-Permeable.—It is very difficult to prepare a satisfactory artificial semi-permeable membrane suitable for demonstrating osmotic pres-

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sure effects. The most suitable, however, is a copper ferrocyanide film deposited in the pores of a porous pot. This substance is produced when copper sulphate and potassium ferrocyanide react together quantitatively, thus :



A porous pot is filled with a 0.25 per cent. solution of copper sulphate crystals and placed immediately into a solution of potassium ferrocyanide of corresponding strength (*i.e.* 0.21 per cent.). Since only one pot in half a dozen or so turns out to be satisfactory, it is best to prepare about six at a time.

Special parchment membranes can be purchased which answer very well when stretched over the head of a thistle funnel, and these sheets should be stored in a 1 per cent. solution of formalin. Alternatively, a dried pig's bladder may be used.

The Microscope.—A good substantial instrument, fitted with a rack and pinion mechanism for the coarse adjustment, and also with a fine adjustment, should be chosen. This type is much better for school work than one of the sliding tube pattern; for the use of the latter often results in smashing the cover-glass and slide and in damaging the object-glass. It is not necessary to purchase a large number of eyepieces (oculars), or object-glasses; two of each will be required, namely, a 2-in. and a 1-in. eyepiece, and a $\frac{3}{4}$ -in. and $\frac{1}{2}$ -in. object-glass.

The term $\frac{3}{4}$ -in. represents the focal length of the combined lenses in the object-glass, and to obtain the best definition, the object should be approximately at this distance from the object-glass and as near the centre of the field as possible. These object-

glasses should be inserted on a dust-proof revolving nose-piece. Object-glasses, especially high-power ones, require every care; for example, they should not be allowed to come into hard contact with the cover-glass. This often damages either the lens itself, or the small metallic mount which projects a little beyond the lens. Perhaps the best method of avoiding this is to focus upwards; that is, the object-glass is placed at a distance a little less than its focal length, *i.e.* $\frac{3}{8}$ -in. or $\frac{1}{2}$ -in., and the tube is raised upwards, using the coarse adjustment until the object is almost in focus. If the movement is carried too far it is often wiser, especially for boys, to start all over again rather than to focus down even a fraction of an inch.

The lenses, eyepieces, as well as object-glasses, should be kept, when not in use, in metallic dust-proof cases. The glass itself should never be touched with the fingers, since this leaves a trace of grease, or of moisture. Small specks of dust often settle on the eyepiece, and their presence there can be detected by revolving the eyepiece in the draw tube. If the dust is on the eyepiece, it will, of course, revolve with it; but if it does not revolve, then it may be on the cover-glass or on the object-glass (the former should be inspected first). The dust may be removed and the lens polished by using an old silk handkerchief; if any dirt or oil still adheres, it may be removed, first by the use of a filter paper dipped in xylol, and then by the piece of silk. The dusting should at all times be done very gently, for the surface of the lens may be easily scratched. It should rarely be necessary to unscrew the systems of lenses, for the dust, etc., is nearly always on the outer surface. Indeed, the lenses composing the object-glass should not be unscrewed except by a skilled person, for the slightest alteration in their relative positions will

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render the combination useless. If it is ever necessary for the object-glass to be dismantled, it is best to allow the makers to do this.

The microscope body should be jointed so that the instrument can be used in an inclined position as often as possible. For when it is used vertically, the observer has to take up an unusual and uncomfortable position. It is therefore necessary to have a stage clip fitted to prevent the glass from slipping off the stage. The microscope should be lifted by the base or pillar and not by any other part. When it is not in use, it should be kept covered in its wooden case, or under a canvas cover, or under a bell-jar. It is advisable to make each student responsible for a particular microscope.

Ruled Eyepiece.—A ruled eyepiece is a cheap device which helps considerably in drawing, especially in getting each part in proper proportion. It is fixed in the centre of the eyepiece tube by unscrewing the top lens of the eyepiece and lowering the ruled glass on to the stop, which will be found about half-way down the tube. When the lens is replaced, the lines on the ruled glass should be in focus. If they are not, the top lens should be unscrewed a little until focus is obtained.

Turntable.—Although the turntable is not much used in school work, it is a useful little instrument for placing a ring of cement round a cover-glass. To do this the slip is fastened to the table by the spring clip, and a camel-hair brush, which has been dipped into the cementing solution, is held against the slip near the cover-glass. As the slip is revolved, a ring of cement is deposited around the slip.

Watch Glasses.—In addition to the usual supply of cheap watch glasses, a few pairs of ground glasses should be obtained. These glasses are ground so that they will fit tightly together when secured by a clip

and so will prevent evaporation from taking place when a volatile stain is placed within.

The Storage of Material

Botanical Material.—Many forms of plant life can be preserved dry; for example, the brown and red seaweeds, many types of fungi (especially the woody types), most mosses and liverworts, ripened cones, seeds and mature fruit, lycopods and equisetum. The method of drying naturally depends on the specimen, for while most may be dried by placing them on unbleached absorbent paper and applying a few weights (see Herbarium, p. 110), others, *e.g.* ripened cones and woody fungi, may be left to dry naturally. Some of the plants adhere to the drying paper, *e.g.* the seaweeds, but the majority of the specimens are placed in water for a few days before use so that they can expand and resume a more normal condition, and this paper can be then removed.

Some systematic plan may be adopted, *e.g.* the smaller specimens may be stored in labelled envelopes arranged alphabetically, while the larger may be kept between large sheets of paper somewhat after the fashion of the herbarium.

A considerable amount of the material will, however, have to be preserved in some liquid. Material required for general morphological study, *e.g.* woody stems, may be placed when freshly gathered in 95 per cent. alcohol for a few days and then transferred to 70 per cent. alcohol for permanent storage. Material so preserved soon becomes brittle; hence it should be soaked for a day or so before use in a mixture of alcohol and glycerin in equal proportions. Algae may be preserved in dilute glycerin (equal parts of glycerin and water) to which a trace of corrosive sublimate, or of carbolic acid, has been added, to prevent the growth of moulds. Large

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fleshy fungi, marchantia and other liverworts bearing gemmæ cups, may be stored in 4 per cent. formalin or in formalin alcohol (see p. 106). Young and immature cones of both sexes may be preserved in 70 per cent. alcohol.

Museum specimens are preserved in a similar manner. It is often useful to display the specimens on a sheet of mica and then to place the mica in the alcohol, when it becomes almost invisible. For example, the various stages of germination can be exhibited by stitching seedlings at different stages fast to the mica.

Zoological Material.—All animals must be killed before preservation and killed in such a manner that no structural alteration occurs at the moment of death, and preserved so that the tissues undergo no change on keeping.

Seventy per cent. alcohol is the general preservative, but since 4 per cent. formalin is very cheap it is also frequently used. But owing to acidity, due to the formation of formic acid (see p. 106), formalin is not a suitable preservative for molluscs and crustaceans and it is not desirable for most fish, amphibians and reptiles. It is quite good enough, however, for echinoderms. Before preservation takes place, it is often necessary to remove certain parts, *e.g.* the soft body contents of the larger crustacea, crabs and lobsters. It is also advisable to dry the exoskeleton on a warm iron plate.

Protozoa may be killed and fixed by the addition of a few drops of a 1 per cent. osmic acid solution to a watch glass full of water, after which the dead animals should be removed to water to wash out excess of osmic acid.

Hydra may be killed, in an extended state, by placing them in a bath of water and heating the latter a little.

Sea anemones must be narcotized first by sprinkling a few crystals of menthol on the surface of the water containing the animals. When narcotization is complete, the animal should be transferred to a 10 per cent. solution of formalin and later stored in 4 per cent. formalin. Magnesium sulphate may also be used as the narcotic. The earthworm may be killed by immersion in methylated spirits; it then requires washing in water.

The fresh-water mussel may be killed by covering it with water and heating it slowly to 40° C. If killed by chloroform, contraction of the foot occurs and the viscera are displaced. The snail can be obtained in the dead expanded state by immersion in freshly boiled water which has been allowed to cool (such water contains no dissolved air). The starfish is usually purchased preserved.

Small crustacea may be fixed by corrosive sublimate or by picric acid, while larger forms can be killed by a short immersion in hot water.

Insects are killed in the cyanide bottle, which is prepared by mixing a little potassium cyanide with plaster of Paris and placing a 2-in. layer of this in a bottle. But if the insect is required for dissection, it should be killed with chloroform. Dogfish are dead when purchased and may be preserved in formalin; it is necessary, however, to inject some of the formalin. Frogs, reptiles, birds and mammals are killed by chloroform.

Skeletons and skulls may be obtained by cutting away as much flesh as possible and removing the brain with a piece of wire and constant washing. The bones should then be immersed in water until all traces of flesh can be removed by scrubbing with soap and a small brush. Unpleasant odours can be avoided by adding a little calcium chloride to the water. The skeleton may then be wired together.

CHAPTER VI

THE PURCHASE OF APPARATUS AND MATERIAL

METHODS of purchase vary in different schools. In some, the senior science master makes out, signs and dispatches the order; in others he does this through his Headmaster; in others, again, he orders his requirements through the Local Education Authority. But in nearly every case he is allowed to spend up to a certain fixed maximum, and he should therefore keep an account of what he has ordered and the amount of money spent.

The actual method of purchasing is usually the same, no matter who finally completes the purchase. Hence the master in charge should have at hand the catalogues of the various dealers and manufacturers (mentioned in the Appendix). A very convenient plan is to have posted in a convenient place in the laboratory a sheet of paper on which he, or anyone else, can make a note of anything of which he notices there is a shortage. When actually making out the order, he should compare the "value for money" offered by each firm. The term "value for money" is used deliberately, since in many cases it is dear to buy in the cheapest market. This applies especially to glassware (see p. 127). Some masters prefer to submit their wants to three or four firms and to get estimates. This sometimes results in "price-cutting" to the advantage of the purchaser, especially when a particular firm happens to have some cheap line it

wishes to dispose of. But it should be made perfectly clear what grade of apparatus is required and who is to pay for the carriage, for this latter amount is often larger than the difference in prices of the tenders submitted. Every firm pays the carriage one way, provided the order is large enough, while the purchaser pays for that of the empty crate, packing, etc. Hence one or two large purchases a year are preferable to spasmodic buying, while a large order to one firm is better than several small ones to many firms. Which firm is chosen often depends, amongst other things, on the fact that a particular piece of apparatus is required and this is sold by one firm only.

Most firms are very punctual in dispatching goods. Those masters who require apparatus at once and who have to purchase through the Local Education Authority, etc., will find that a letter sent to the firm, at the same time as the requisition is sent to the Authority, will hasten matters. Then the vendors will have the goods ready for dispatch on receipt of the proper order.

When the goods arrive, the master, or school porter, should sign the carrier's sheet "not examined." The articles sent must be checked with the invoice enclosed and any breakages noted. Few, if any, firms will replace or make any allowance for breakages. The carriers are responsible for these, and therefore any claim must be sent to them within three days of receipt. The vendors should also be notified, since many of them will recover damages from the carriers on the master's behalf.

All "empties," including the packing and even the straw, are charged for, and should be returned in a good condition, when credit will be given for them.

The Purchase of Chemicals.—Most of the

chemicals can be bought from one of the large manufacturing firms, or from the local chemist. It must be pointed out that, when the latter method is adopted, the chemist usually purchases from one of the manufacturers, for he rarely carries a stock large enough to supply a school laboratory. It is thus often possible to save the "middleman's" profit by purchasing direct.

Chemicals are divided into three classes according to their degree of purity—commercial, pure, and puriss (*i.e.* purissimus). Which variety is purchased naturally depends on the chemical and the use to which it will be put, and the reader is referred to the chapter on Chemical Reagents on this point.

Acids and certain inflammable liquids present some difficulty, owing to the regulations of the railway companies. The carriage rate is very high, owing to the special precautions that have to be taken in transit, and it is therefore much cheaper to buy a large quantity at a time. Of course, when the chemicals are sent by road, this difficulty frequently does not occur. It is often very convenient to buy such substances from the local chemist, who orders them in bulk and can afford to keep a larger stock than a school laboratory would. He is thus in a position, if he is so disposed, to give the master some of the benefit accruing from a large purchasing. Indeed, it is always advisable to deal with one of the local chemists. There occasionally arises a time when some particular substance is required at once, and naturally the chemist will do his best to oblige a regular customer.

Most of the containers, bottles, etc., are charged for, and often at exorbitant rates. Therefore, on receiving supplies, the master should check the account with the bottles and see that the amount at which the bottle is charged is clearly marked on the

bottle, as well as the vendor's name. Empty bottles should be returned at convenient times and credit for them claimed. It is not necessary to purchase many chemicals in bottles; but since most vendors supply bottles unless otherwise ordered, the master should state clearly on his order form the substances for which he does not require bottles.

The Purchase of Alcohol.—One of the chief drawbacks to the use of alcohol has now been removed, and it is no longer necessary for the science master to pay the heavy duty on this substance that the ordinary individual has to pay. With the privilege of purchasing alcohol free, or almost free, of duty, there has been imposed, however, the necessity of complying with certain formalities and restrictions of which the following are the chief:

Methylated Spirit is on the market in two varieties—Industrial Methylated Spirit and Mineralized Methylated Spirit. The former is the variety with which we are concerned. It is a mixture of ethyl alcohol and wood spirit, containing about 95 per cent. of ethyl alcohol. It differs from mineralized methylated spirit (which is the common methylated spirit) in that it contains no mineral naphtha, pyridine or violet dye, and has a smaller percentage of methyl alcohol in it.

The Industrial spirit can be bought only by approved persons, who must have received beforehand the authority of the Commissioners of Customs and Excise to use it. Teachers in science schools may become "approved persons," but usually the Headmaster is the person authorized. Not less than five gallons at a time can be purchased, and a bond must be given for its proper use.

Amongst other conditions the following apply particularly to teachers. The spirits must be used solely for the purpose sanctioned and in the state

in which they are received. They must not be sold, recovered or redistilled. Moreover, the Revenue Officers have the right of free access to the room in which they are stored and used; they have to satisfy themselves that the spirit is kept under lock and key in the control of some responsible person. A form stating the amount used per annum has to be sent to the Revenue Officer each year (ending March 31st); hence the master should keep an account of the amount and date of the purchase.

Requisition Forms, on which the order must be made, are supplied free of cost by the local Customs and Excise Officer, to whom application must be made for a book, containing about twelve of such forms. The form, when completed, must be sent by the purchaser direct to the Methylator. Five gallons should be ordered at a time, and this amount lasts a considerable time.

The Methylating Co., Ltd., Chancellor's Road, London, W.6, willingly supply schools, and the specimen copy, p. 125, shows how the form of request note and counterfoil should be completed.

It is necessary to fill the counterfoil in carefully and to sign it at the time of purchase.

On receipt of the drum containing the spirit, the permit, which is usually attached to the label, must be secured and pinned to the appropriate counterfoil ready for the Revenue Officer, who generally calls for it within a few weeks of the purchase.

The procedure is, therefore, quite simple, and even small schools will benefit, since such alcohol costs only about 3s. per gallon. This alcohol is good enough to use in such organic preparations as ethyl hydrogen sulphate, ethyl chloride, chloroform, etc., as well as for preserving specimens for biological work.

Absolute alcohol cannot be purchased duty free for

No. 1.

REQUISITION FOR

Industrial Methylated Spirits

—

Date September 30th, 1928.

125

Quantity*

Five Gallons

From The Methylating Co., Ltd.,

Of Chancellor's Road, W.6.

Signature EDWIN SMITH

Headmaster.

No. 1. London District

THE HEADMASTER

of School is authorized

by the COMMISSIONERS OF CUSTOMS AND EXCISE to receive

INDUSTRIAL METHYLATED SPIRITS.

GEORGE WESTON *Officer.*

I hereby request you to supply me with* Five Gallons of

INDUSTRIAL METHYLATED SPIRITS.

Date September 30th, 1928

To The Methylating Co., Ltd.

Signature EDWIN SMITH

of Chancellor's Road, W.6.

Headmaster.

*N.B.—The number of Gallons must be expressed in Words.

(This form is printed in Blue Ink)

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(This form is printed in Blue Ink)

use in a school laboratory, although Universities and Colleges may so obtain it. The school authorities may purchase it on payment of the full duty of 74*s.* a proof gallon and may claim a rebate of 59*s.* 3*d.* per proof gallon on the quantity used every three months. The regulations and requirements are very troublesome, and particulars of these, as well as the necessary forms, may be obtained from the local Customs and Excise Officer.

The Purchase of Biological Material.—For the teaching of Elementary Botany and Nature Study very little material will be purchased. Part of the students' training consists in collecting and bringing to school such specimens as are required, and usually the school syllabus will be based on the plants, etc., found in the locality of the school. Moreover, if there is a school garden (see p. 110), supplies can be grown there, while many specimens can be obtained from the aquarium, or some neighbouring pond. Even in large towns, excursions can be made into the surrounding country, or specimens and facilities for study obtained by reference to the municipal or park authorities.

Few schools, however, are situated so that all types of plants and animals are available, especially for the advanced students. Hence purchase has to be made from firms who specialize in supplying schools. Examples of the various plant associations, microscopic preparations, materials for histology and so forth can be obtained from such firms, some of which also specialize in supplying weekly boxes of specimens for lessons based on their own or any other syllabus, at £2 for ten boxes.

Marine plants and animals may be obtained from one of the biological stations. Often a local fishmonger will supply fish, crabs, pigeons, rabbits, etc. These, with the exception of fish, should be obtained

alive and killed by the teacher. It is usually necessary to give a few days' notice when fish are required, otherwise the fish may be sent with all the contents of the body cavity missing. If there is any difficulty in obtaining any specimens, application may be made to one of the University Laboratories.

The Purchase of Glassware.—Every laboratory requires an adequate supply of glass vessels, and unless great care is exercised, much money will be wasted, for, of all articles used, glass is the most variable in quality. No apology is necessary, therefore, for the somewhat detailed account given below.

In pre-war days, German and Austrian manufacturers held the monopoly in the supply of laboratory glassware. Indeed, there were few British firms that specialized in such articles. This was chiefly due to the British manufacturers concentrating on flint glass and having their furnaces adapted for melting a lead glass. The Continental firms, however, adapted their furnaces for a lime-soda-aluminium glass, which is much superior for chemical work. During the war, at the request of the Government, the British firms turned their attention to the production of laboratory glassware and were under very great difficulties through lack of knowledge, materials and skilled workmen. Naturally, the glassware produced at first was by no means perfect, and hence British glass became viewed with a certain amount of suspicion. After much research, the quality was improved to such an extent that to-day British glassware is equal to any Continental brand. But, with the typically British characteristic, our manufacturers do not shout their wares from the house-tops; hence the belief still exists in many quarters that German glass is a superior article. It is necessary to dispel this belief, which has now no foundation,

and science masters may feel sure that they can purchase British goods even on other than patriotic grounds.

A satisfactory glass for laboratory purposes should possess three qualities. It must be resistant to chemical action, to sudden and extreme changes of temperature and be mechanically strong. These qualities seem to be best developed in a glass containing some of the following constituents, about 74 per cent. of silica and the oxides of sodium, potassium, boron, aluminium, calcium and zinc.

It will be seen from a study of these constituents that no glassware is free from attack by caustic alkalis, or by water under pressure. There is a limit over which such an attack becomes dangerous, and the successful manufacturer has to choose his materials and quantities with care, depending on what particular characteristic of the glass he desires to lay stress. It may perhaps be not without interest to describe the manner by which glassware is examined for these characteristics.

Tests on Glassware.—Samples of most of the reliable varieties of glassware manufactured in England are submitted to tests of the following nature, carried out by some independent body, such as the National Physical Laboratory, or by the Department of Glass Technology, Sheffield University. The tests are usually applied to beakers and flasks and are made to investigate the thermal endurance of the glass, its mechanical strength and the action on it of water and chemical substances.

The thermal endurance test is made by placing paraffin wax in a number of beakers, etc., and heating them until the wax has melted and attained some definite temperature. The vessel, whilst still at this high temperature, is immediately plunged into water at 15° C. or 20° C. This process is repeated by heat-

ing the wax to a higher temperature until all the beakers under test have broken or cracked. The average temperature at which cracking takes place is a measure of the thermal endurance of that glass.

The mechanical strength obviously depends to a great extent on the thickness of the walls of the vessel. A comparative test is made by dropping specimen flasks, etc., from a known height on a board so that the bottom falls squarely. The height at which the vessel is dropped when breakage occurs gives an indication of its mechanical strength.

Water, under pressure especially, dissolves some of the alkali from the glass, and a test is made to discover the amount dissolved. The vessel is partly filled with distilled water and heated for a few hours, under a pressure of four atmospheres, in an autoclave. Special precautions have to be taken to protect from splashing, etc. At the end of this experiment, the amount of sodium oxide extracted per unit area, as well as the weight of soluble matter removed from a definite area, is calculated. These results serve for comparison when tests are made, under similar conditions, on different varieties of glass. The action on the glass of hydrochloric acid, sodium hydroxide, ammonium hydroxide and ammonium chloride is also investigated. In each case the vessel is filled with a certain volume of the reagent of known strength and heated for a definite period. Finally, the amount of solid removed from a definite area, e.g. from one square decimetre, is determined.

Silica Ware (*Vitreosil*).—Many pieces of physical and chemical apparatus which were formerly made of glass are now being manufactured from vitreous silica, made by fusing ordinary silica electrically, and which contains over 99 per cent. silicon dioxide.

It is manufactured in two varieties—a transparent variety, which is transparent to light and ultra-violet rays, and the translucent variety, which is opaque and quite suitable for ordinary laboratory purposes.

Silica has a low coefficient of expansion, 0.00000054, *i.e.* one-seventeenth that of glass, and largely because of this property, vessels made of it may be subjected to rapid and extreme changes of temperature with safety. Indeed, such a vessel can be heated to a red heat, and, while it is still in the flame, cold water dropped on to it without any breakage and without the material suffering. This is of course due to that part which is cooled contracting so very little that no appreciable strain is set up in the material.

On prolonged heating, at very high temperatures, there is a change in its physical properties, and the vitreous silica becomes devitrified and hence loses its mechanical strength. But investigations carried out at the National Physical Laboratory show that this does not take place under 1100°C. , which is therefore a safe working temperature.

Silica has a high melting-point, and so may be used for retorts, muffles, combustion tubes, pyrometers, etc. It is quite insoluble in water (glass is not), and is unaffected by nitric, sulphuric, or hydrochloric acids, or by a mixture of these acids at any temperature or concentration. Of the acids, hydrofluoric and glacial phosphoric alone have any action on it. The former attacks it to one-tenth the amount it attacks glass; concentrated phosphoric acid attacks it seriously over 400°C. , but only slightly from 220°C. upwards. It is affected, however, by alkaline solutions and certain metallic oxides at high temperatures, glasses being formed. Therefore such substances should not be heated in silica vessels unless kept out of contact by means of asbestos.

The advantages of such a ware are many. Since there is no danger of breakage owing to unequal heating, work can proceed rapidly; there is no necessity, for example, to wait for the vessel to cool before adding a cold solution to it. Neither is there the danger of a beaker or crucible being broken through careless or over-heating, and so the fear of spoiling a few days' work by careless heating is removed.

Silica ware is considerably dearer than glass, but there are occasions when initial economy in the purchase of glassware, etc., is a false saving. Some of this silica apparatus is almost indestructible, and it may be economical in the long run to purchase at the outset certain pieces of apparatus. For example, an ordinary pipe-clay triangle costs 4*d.* and has quite a short "life"; a silica one of the same size, mounted on iron wire, is 6*d.*, or on chrome-nickel wire 9*d.* The latter will not rust and should last for years.

Graduated Glassware.¹—For most school laboratory purposes, graduated glassware of "School Quality" is sufficiently accurate, except perhaps for advanced work. Even for such work ordinary apparatus will serve after it has been calibrated. Most books on quantitative analysis describe methods of calibration, and this exercise is not beyond the capabilities of the average sixth-form student. Generally it will be found that, by a judicious selection from the "School Quality" apparatus, vessels requiring little alteration can be chosen. But the master himself should have for his own private use an accurately calibrated set, including a burette, pipettes, flasks, specific gravity bottles, etc. In England this calibration is carried out at the National

¹ See *Tests on Volumetric Glassware*. N.P.L. Pamphlet.

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Physical Laboratory, and vessels which have passed the required tests are marked accordingly. Thus those of Class A accuracy are etched ^{N.A.} '24', this being a monogram of the initials N.P.L. together with the letter A and the year the vessel was tested.

Vessels which pass Class B tests are etched ^{N.B.} '24'.

Class A vessels possess the highest accuracy, and along with them is issued, when desired, a certificate stating the results of the tests applied and bearing a registration number which is also etched on the vessel.

Class B vessels are "intended to possess only Commercial accuracy" and certificates are not issued in connection with them. The standard of accuracy is indicated by the following examples:

100 ml. flasks,	Class A	± 0.06 ml.,	Class B	± 0.1 ml.
1,000 ml. flasks,	„	± 0.2 ml.,	„	± 0.4 ml.
20 ml. pipettes,	„	± 0.02 ml.,	„	± 0.05 ml.
100 ml. cylinders,	„	± 0.4 ml.,	„	± 0.8 ml.

In addition, Class A vessels must fulfil other requirements, *e.g.* pipettes must deliver the solution in a certain time, the delivery jet of the burette must be of a certain type, and where necessary, the vessel must be distinctly marked, *e.g.* a pipette marked

^{50 ml.}
D. 15° C. is one which delivers (hence D) 50 ml. of
(30 + 15) sec.,
water at 15° C. in thirty seconds and requires fifteen seconds to drain finally. (If the pipette were meant to *contain* this amount, the vessel would be marked C instead of D.)

The following additional information may be of interest. The position of the meniscus is read, in the case of water, when the lowest point of it coincides with the mark; in the case of mercury, when

the upper surface coincides with the mark. When a pipette is being graduated, it is filled to the graduation mark and clamped in a vertical position. The adhering drop is removed by bringing it into contact with water. The pipette is then inclined so that the jet touches the side of the vessel, and is allowed to drain for fifteen seconds while still in this position. The last drop is removed when the pipette is withdrawn from the side of the vessel. Since a pipette is graduated in this fashion, it must, therefore, always be used in a like manner.

Vessels tested by the National Physical Laboratory are naturally expensive, the prices for testing certain articles being as follows (subject to a discount for large quantities):

Burettes: Class A, 12*s.* 6*d.*; Class B, 9*s.*

Pipettes, 5 to 25 ml.: Class A, 3*s.* 6*d.*; Class B, 2*s.* 6*d.*

Flasks, 100 ml.: Class A, 3*s.*; Class B, 2*s.* 3*d.*

In addition, the workmanship has to be of a superior quality; otherwise, the vessel is rejected on that account alone.

General Remarks on Glassware.—From the foregoing it is perhaps obvious that cheap, unbranded glassware should not be purchased. It may cost half as much as the branded though it frequently does not, but it certainly does not last twice as long, and this after all is the true test of cheapness. It is necessary to add that many Continental firms flood the British market with their cheap soda glass, or a very inferior resistance glass.

Until recently, there has been such a big difference in price between branded and unbranded test-tubes that the science master has hesitated considerably before buying a high quality one. But to-day at least two varieties can be bought at what are really competitive prices. In a large laboratory, much

money is expended on test-tubes and it is perhaps necessary to state a few of the characteristics a good test-tube should have. It must be capable of standing a fair amount of heat without cracking, it must be sufficiently strong not to crush when held in the hands or in the holder, and at the same time must be cheap enough so that it can be thrown away after certain experiments. Cheap tubes possess only the latter characteristic. The worst purchase the author remembers making was one of ten gross of test-tubes at 6s. 6d. per gross. These tubes, German in origin, lasted much less than half the time the next purchase of tubes at about 10s. 9d. a gross. They often broke in the fingers, many of them developed "spiral trouble" even before being used, and scarcely one of them remained intact at the mouth the first time the students placed them upside-down in the rack to drain.

Porcelain Ware.—As in the case of glassware, the German manufacturers turned out porcelain ware of a much superior quality than did the British firms in pre-war days. Since the war, a great deal of research has also been carried out in this field by at least one British firm, so that at the present time British scientific porcelain can rival that of any Continental firm.

The raw materials of porcelain are clay, silica and base bearing minerals. After burning and subsequent cooling, these materials yield a hard porcelain, which is chemically a heterogeneous mixture of a crystalline form of aluminium silicate, called sillimanite, silica and basic oxides of aluminium and potassium.

Porcelain for laboratory purposes should fulfil two requirements; it must not be porous and must have great resistance to fracture on heating to high temperatures. This latter property is closely associated with the efficiency of the formation of sillimanite,

and this is the problem which confronts the makers. Porcelain is made non-porous by the addition of a glaze, and it is essential that this glaze should expand at an equal rate with the body of the vessel. Moreover, the glaze must not soften between 1050° C. and 1100° C. and it must be impermeable to gases up to 1350° C.

The following tests, furnished by the Worcester Royal Porcelain Company on methods of testing a high-grade chemical porcelain, are interesting.

How to Test a High-grade Chemical Porcelain

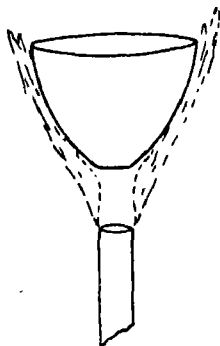
TEST 1. A small crucible or a glazed fragment of a larger vessel is held in a bunsen flame until the greater part of it is red hot. It is immediately dropped into a solution of cosin or iodocosin, and after removal and cleaning, examined.

This test gives evidence as to the approximation to equality of body and glaze. A close approximation leads to a surface cracking which forms an imbricated pattern of curved cracks which do not extend deeply into the body, but rather give a tendency to scaling through overlapping in a lateral direction. Low quality porcelains give cracks with angular intersections which penetrate deeply into the body, making it extremely brittle.

TEST 2. A crucible $2\frac{3}{4}$ in. diameter is heated over a bunsen burner as shown in diagram; care being taken to reproduce the illustrated deflection of the inner cone of the flame by the base of the crucible. Continue heating for a quarter of an hour.

In this test a heavy strain is placed on the base of the crucible which is at about 100° C., while the sides are from 800° to 900° C. It is, in fact, one of the severest tests that a good porcelain should stand,

and a certain proportion of failures occur in the best makes. Crucibles above this size always fail, but the smaller sizes should always stand, unless the bunsen flame is particularly fierce.



TEST 3. A combustion boat is filled with fragments of the same porcelain and heated in a combustion furnace from 1050°C. to 1100°C. in four hours. On removal, the pieces should be detached by the fingers or a sharp tap.

The hardness of the glaze here tested is important since, as a general rule, the solubility of a glaze in reagents varies inversely as its hardness. Soft glazes, which cause the pieces to be so firmly attached that removal may incur the breaking of the boat, usually have high solubility values.

CHAPTER VII

ACCIDENTS IN THE LABORATORY

ACCIDENTS are bound to happen in the best conducted laboratory and, therefore, the science master must be able to render first aid. Sometimes these accidents are due to the negligence of the teacher, and then he and his employers become liable at law to damages. It may therefore be of interest to outline what appears to be the legal position of a master.

Except in a few private schools, the teacher is the servant of the school governors or the Local Education Authority; these are responsible for any negligent act of their servant. Hence action is usually taken against the Authority and the teacher combined, and the Authority defends. The precedent for this is the case of *Ching v. Surrey County Council*. In this case it was submitted that a County Council could not be held liable for any negligence of their official; that they were in a similar legal position as a Board of Guardians, and that previously such a body, since they discharged ministerial duties, had been held not to be liable for the negligence of an official (see *Tozeland v. West Ham Union*). But this was not maintained, and damages were awarded against the County Council. A more striking case was that of *Smith v. Martin and the Mayor and Corporation of Kingston-upon-Hull*. In the lower court it was held that the Education Authority (the

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Mayor, etc.) was not responsible for this particular act, since, although negligence had been proved to have taken place in school and during school hours, it was due to an act not necessary for the carrying on of the school. On appeal, however, this judgment was reversed, and the Authority was held jointly liable, presumably on the ground that the child obeyed the teacher's order and that the Mayor, etc., had placed the teacher in a position of authority over the child.

The law recognizes that accidents will happen and allows for no compensation unless it can be proved that the injury or damage is due to negligence. Thus, the crux of each case is the question: What is negligence? and this is decided by a jury, subject of course to the Judge's directions on points of law. Generally the defence is a denial of negligence, or alternatively of contributory negligence on plaintiff's part. A few cases are quoted to show what "negligence" has been found to be.

In the case of *Williams v. Eady*, the plaintiff was a boy who had been burnt with phosphorus. It appeared that at defendant's private school chemical lectures had once been given, but later were abandoned. Instead of destroying the phosphorus, the master had placed it in a cupboard in the conservatory, along with cricket things, etc. The cupboard, he submitted, was kept locked and the keys deposited in the kitchen. In some manner a boy, not the plaintiff, had secured access to the cupboard and extracted the bottle of phosphorus. Into this he plunged a lighted match, shook the bottle and waited. But not for long, of course, for the bottle exploded and in doing so injured the plaintiff, who was passing by. The defendant lost the case both in the lower and higher courts, on account of negligent storage.

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A few observations made and rulings given in this case will be quoted, since they will probably influence any other case. It was made clear that negligence was a question of degree. For example, as the Judge pointed out, it may be negligent if one left a knife where a boy of four could get at it, but it would not be so for a boy of eighteen. It was also realized that a master had to leave dangerous things lying about. But when he did so, he must take such precautions as a prudent man would be expected to take. Moreover, allowance must be made for boyish nature, for the tendency of boys to do mischievous acts and to meddle with things. Notwithstanding this, negligence could not have been proved in this particular case had the teacher kept the cupboard securely locked. Evidently, as was pointed out on appeal, the jury found that this had not been done.

Another case involving phosphorus burns is on record which had a happier result for the teacher. The plaintiff sued the Essex County Council and others (the teacher). It appeared that the master gave out pieces of phosphorus to the boys who were working in pairs for a certain experiment. Plaintiff put a piece in his pocket and sent his partner for another. In time the phosphorus caught fire, burnt a hole in plaintiff's pocket and severely burnt his leg. The most important question was, "Did the boy know of the dangerous nature of the phosphorus?" It was held that he did, for, although he had not been warned in that particular lesson, he had been by a previous master. No doubt the plaintiff lost the case because he had taken the phosphorus for his own use and was not injured in following out any special instructions. It is problematic what the verdict would have been had the boy been injured in the performance of the experiment, even though

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it was held that he had not been left in ignorance of the danger involved in using the substance.

In the case of *Smith v. Martin* (see above), the teacher sent a girl to poke the fire and draw the damper in the teacher's common room. In doing this the girl was severely burnt and was later awarded damages, notwithstanding the submission that the girl was aged fourteen, often attended to the house, had been trained in domestic science and was bright and intelligent for her age.

In *Smerkinisch v. Newport Corporation* a youth was injured whilst working a circular saw. This saw was not protected by a guard, but the youth knew this, and in spite of it, had asked for and obtained permission to use the saw. In short, he knew of the risk and accepted it, and thus he himself was held to be responsible for the injury and the Local Authority was dismissed from the suit. The youth was, however, nineteen, and evidently it was thought he had reached an age of discretion.

So far as the author is aware, only two post-war cases have been before the courts. In one the master sent a boy to fetch a Winchester bottle of concentrated acid. This the boy dropped and received severe burns. The master was held negligent in sending a boy for such a large bottle, the boy's hands being judged to be too small to grasp it properly. In the other (*Foster v. London County Council*), a teacher ordered a girl to remove a rusty pen-nib by means of a pair of pincers. In doing so the nib broke and a piece flew into the girl's eye, thereby injuring it. The teacher was held responsible, since she had not given any instructions on how to use the pincers.

The position as affects the science master seems to be as follows. He is teaching a subject where accidents will happen and one the Education Authority compels the student to take. That is, the pupil

is not in the same position as the plaintiff in *Smerkinisch v. Newport Corporation*; that is, he does not accept the risk voluntarily. At least he does not when attending an elementary school, since he is legally bound to attend school until he is fourteen. Whether he would have been held to accept the risk in a secondary school is problematic; legally he is not bound to attend one. But when the Education Authority admits him to the school, they must take reasonable care that while he is under their care no harm befalls him. That is, on attending a secondary school the boy (or his guardians) knows he will have to take science and thereby accepts a certain amount of risk, but this does not excuse a master from warning the boy when anything of an exceptionally dangerous nature has to be used. In short, the teacher cannot very well guard the boy from ordinary cuts from broken glass, etc.; but if he orders a boy to cut a piece of glass tubing, he must give proper directions as to the use of the file. Or, if he has a boy fitting up a piece of apparatus, he must ensure that the boy knows how to do it, *e.g.* he should show him how to insert a glass tubing through a cork and not leave the boy to push it through by force, and so on. (The prevention of accidents is dealt with more fully below.)

If the master himself is injured during the performance of his duty, it is very doubtful whether he can hold the Education Authority liable for damages unless he can prove negligence on their part. At least one such case is on record, *Abbott v. Isham and Others*, where the master was injured by the pipes bursting. In this case the Managers of a non-provided school were held responsible, since the teacher had reported on the unsatisfactory state of the heating apparatus and they had not taken steps to have it remedied. Otherwise, however, the position seems to be that

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the science master, on accepting his situation, thereby accepts voluntarily any risk. He may, of course, insure against accident, if he so wishes, with the underwriters.

The Prevention of Accidents

The old maxim "Prevention is better than cure" is an admirable one for science masters. Quite irrespective of legal or financial considerations, the students have a personal, if not moral, right to be told when any experiment involving risk has to be performed. A general warning that work in a science laboratory has special dangers is not of much value, for there are so many experiments where the risk is negligible, and so many of these are performed by a student early in his studies that familiarity breeds contempt. Substance A may be perfectly harmless when heated, while substance B may explode; substance C can be handled with impunity, while substance D is spontaneously inflammable in air. The pupil cannot be expected to know this and must be put on his guard when needs be. The following experiment and substances involve risks of which the students must be informed beforehand. The list below is not, of course, meant to be exhaustive.

Cuts from Glass.—This type of accident is very common. Usually cuts are caused through the pupils' carelessness and occasionally through ignorance. Every pupil should be shown how to cut a piece of glass tubing, and have impressed upon him that force is not necessary. After the glass has been cut, the edges should be rounded off in the bunsen flame so that no sharp points are left. Even the insertion of a tube through the hole in a cork may result in a nasty cut. Boys will grasp the end of a tube, or a thistle funnel in the palm of the hand, and push as much as possible. This is quite unnecessary. The

tube should be inserted by a screwing motion, gently and gradually. If it does not enter easily, as is often the case with a rubber stopper, the glass should be wetted with water, glycerin, or caustic soda. If the hole is too small, it must be made larger by a rat-tailed file (not by the glass tubing), or a new cork must be selected.

Most test-tubes are thin-walled and should not be squeezed in the hand. No glass apparatus of any kind must be screwed fast by means of a clamp unless the jaws of the clamp are covered with cork, or a piece of paper is wrapped round the glass. Broken pieces of glass must not be left lying about, but placed immediately in the waste box, not in the sink. Notwithstanding this, the sink must be carefully examined for glass before it is cleaned.

Precautions when Heating Glass Vessels.—Beakers and flasks, especially when containing solid, and liquid at the same time, must be heated gradually at first. The naked flame should never play on the glass above the level of the liquid, and all moisture and dirt must be wiped away from the bottom of the vessel before use. The use of a wet piece of wire gauze invariably results in a broken vessel. Similarly, if a flask is to be heated on a sand tray, the bottom of it must be perfectly dry. If it is not, the water is converted into steam, which scatters the sand in all directions, and may cause the flask to break. Evaporating basins should be heated similarly on a pipe-clay triangle or sand bath, not over wire gauze.

Hot vessels must not, of course, be cooled quickly. Many boys will unthinkingly place a hot crucible under the tap to wash it, or else place it on the cold foot of the retort stand. When a vessel is being heated, on no account should the bunsen burner be held immediately underneath the vessel by hand. The vessel may possibly break and the contents, if only

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hot water, may cause serious burns, while acid, etc., may do irreparable injury.

There is also the danger that boys will burn themselves with a piece of glass after it has been heated. It must be pointed out that glass retains its heat for a considerable time after it has ceased to appear hot.

Use of Wrong Substances.—To avoid using the wrong substance, every bottle should be distinctly labelled (see p. 33). Many pharmaceutical chemists have the habit of reading the label, *i.e.* actually saying the words to themselves. This is a wise precaution, as is that of looking at the label twice, once when getting the bottle, and again after removing the stopper and just before adding the solution. The stopper should be replaced immediately after use.

A good method of pouring out liquids is to hold the bottle in the right hand and the test-tube, etc., in the left. The stopper is removed by grasping it between the little finger and the palm of the left hand and retained thus until it is replaced.

Substances given out should always be labelled in some manner.

Inspection of Apparatus.—It should be the rule in every laboratory where juniors are working, that the actual experiment must not be begun until individual permission has been given. That is, the pupils must fit up their apparatus and get everything ready to begin and then inform the master. He should give permission to heat certain substances, add concentrated acids, connect to batteries, etc., and should look for the obvious mistakes in fitting up the apparatus.

Some Substances requiring careful Handling

Acids, Concentrated.—All concentrated acids are corrosive substances and must never be allowed to

come in contact with the flesh. In addition, most of them give off fumes of a very irritating nature.

Acetic Acid, Glacial, fumes strongly and occasionally causes blisters to appear.

Carbolic Acid or Phenol.—As weak a solution as one of 5 per cent. causes some numbness, often followed by intense irritation. A stronger solution causes a white scar to form, which in time drops off, leaving a yellowish stain.

Chromic Acid irritates and corrodes the skin a little.

Formic Acid is a very volatile liquid whose fumes must not be breathed. A drop of this acid is very irritating to the skin, usually producing ulcer-like spots.

Hydrochloric Acid is not nearly so corrosive as the other common mineral acids and has little effect on the flesh, unless it is in contact with it for a considerable time. It fumes very readily and these fumes have a choking effect if inhaled for a long time.

Hydrofluoric Acid is a very dangerous liquid to leave lying about. It fumes very readily and these fumes attack the respiratory passages with some violence. Moreover, the concentrated acid produces blisters on the skin which, besides being painful, are very difficult to cure.

Nitric Acid is one of the most corrosive of acids. In addition, it turns the skin yellow, ultimately causing it to peel off. Special care is necessary when acting on this acid with metals or organic matter (see Nitrous Fumes, p. 151).

Sulphuric Acid is also very corrosive. If it remains in contact with the skin for some time, it produces very serious burns, resulting in deep seated and permanently disfiguring scars.

Organic Acids.—Most of the organic acids used in a school laboratory, with the above exceptions, are of a much milder nature and produce little corrosion unless in contact for a considerable time.

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Water should, as a general rule, never be added to a concentrated acid. Under no circumstances must it be added to concentrated sulphuric acid (see p. 71).

Alcohol.—The alcohols are inflammable. Care is necessary in the alcohol-nitric acid reaction (see Nitrous Fumes).

Aldehydes. Formaldehyde.—The fumes of this substance are very irritating to the throat, etc., and have been known to produce bronchial catarrh. Generally speaking, the other aldehydes are much less harmful, with the possible exception of paraldehyde.

Alkalies.—Concentrated solutions corrode the skin and may ultimately produce ulcers.

Ammonia.—Liquor Ammoniae Fortis fumes strongly in air and great care is necessary on opening the bottle. The vapour is poisonous.

Ammonium Iodide explodes on heating.

Ammonium Nitrate is a common constituent of many explosives. It must never be ground in a mortar with other substances. These should be ground separately and mixed together on a sheet of glazed paper by means of a feather, etc. The ammonium nitrate often explodes when heated alone. Hence, in the preparation of nitrous oxide, a mixture of ammonium sulphate and sodium nitrate should be employed.

Ammonium Nitrite also explodes on heating. A mixture of ammonium chloride and potassium nitrite should be used in the preparation of nitrogen.

Amyl Nitrite.—The fumes from this liquid have a powerful effect, causing the blood to run to the head, a flushing of the face, and an increase in the rate of beat of the pulse. It should therefore be used very cautiously.

Aniline is a blood poison, and since it can be absorbed through the skin, must not be allowed to come in contact with any part of the body.

Arsenic.—The poisonous nature of this element and its derivatives is too well known to need any amplification. Especially is its use dangerous, since many of its compounds are volatile. The hydride, AsH_3 , is exceedingly poisonous; 1 part in 100,000 is dangerous if breathed for some time.

The fumes produced in the cacodyl test are also of a very poisonous nature.

Benzene fumes produce headaches and giddiness, as do the fumes of its homologues, toluene and xylene.

Bromates.—These substances react in a similar manner to the chlorates, but are much less vigorous.

Bromine is a fuming volatile liquid. The fumes have a very irritant action on the mucous membrane and often cause inflammation of the lungs. So little as 1 part in 100,000 is said to be injurious, whilst 1 in 3,000 has produced fatal results. The fumes also attack the eyes and produce severe pains, often with dangerous results. The liquid, on contact with the skin, produces a nasty burn.

Carbon Dioxide is suffocating, but its preparation is attended with little risk and can be performed in the open.

Carbon Monoxide.—The poisonous nature of this gas can scarcely be over-exaggerated: 5 parts per 10,000 have a poisonous effect, while 2 parts per 1,000 are dangerous to life. Moreover, it attacks very suddenly, with little, if any, warning, and death results in a few minutes.

Chlorates.—All the chlorates are powerful oxidizing agents and explode very readily. Potassium chlorate will explode if heated by itself to a high temperature, or when heated to a very low temperature with phosphorus, sulphur, carbon, antimony, sulphide, concentrated sulphuric acid and many organic substances. It should never be ground in a mortar with other substances; instead treat it in a

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similar manner as mentioned under ammonium nitrate (see p. 146).

Chlorine.—The poisonous nature of this gas is also very well known; 1 part in 100,000 is injurious, 1 in 3,000 fatal.

Chlorine, its Oxides.—All the oxides of chlorine are explosives. Liquid chlorine monoxide is said to explode when poured from one vessel to another. The gas will also explode on contact with phosphorus, sulphur and many other substances, chiefly organic. Both the peroxide and the heptoxide have similar properties. Hence their preparation must be done only by an experienced chemist.

Chromic Acid.—A mixture of this substance and glycerin explodes when heated; the mixture has been known to explode when scratched.

Copper Acetylide explodes when heated and occasionally if rubbed, provided it is dry.

Cyanogen is a very poisonous gas.

Cyanides.—See Potassium Cyanide.

Dinitrobenzene.—The preparation of this substance requires great care. The fumes cause headache and sleeplessness and are injurious to the eyes. The solid can be absorbed through the skin and so poisons the blood. It should therefore never be handled.

Explosions with Oxygen.—All these should be performed in a thick walled vessel around which has been wrapped a piece of cloth, duster, etc. The following mixtures are especially explosive. One volume of oxygen with two of hydrogen, or half a volume of methane, or a third of a volume of ethylene, or two-fifths of a volume of acetylene, or half a volume of carbon monoxide.

Fluorine and all its compounds must be carefully treated. The fumes are particularly obnoxious and poisonous.

Formaldehyde.—See Aldehydes, p. 146.

Gunpowder.—The constituents of this mixture must not be ground together in a mortar, but each one ground separately and then mixed. Occasionally gunpowder is set on fire in an open space to demonstrate the amount of gas evolved. It must be remembered that the fumes produced contain about 10 per cent. carbon monoxide and $2\frac{1}{2}$ per cent. of hydrogen sulphide, and are therefore poisonous.

Hydrogen.—The preparation of hydrogen is attended with great risk unless care is exercised. Hydrogen and air form an explosive mixture. Therefore, before the gas is set alight, it must be tested, by taking a sample in a test-tube and applying a light. Where elementary students are allowed to prepare this gas for themselves, the teacher should issue strict instructions that he himself must be present when the gas is tested and the light applied.

Hydrogen Cyanide is a very volatile liquid indeed, producing fumes which are exceedingly poisonous. A solution is also poisonous when taken internally, and therefore must never be sucked into a pipette.

Hydrogen Fluoride.—See Hydrofluoric, Acid p. 145.

Hydrogen Sulphide is a more dangerous gas than is perhaps commonly supposed: 5 parts per 10,000 is certainly injurious; twice this amount has been known to be fatal. In smaller quantities the gas produces headache, giddiness and irritation of the mucous membrane.

Inflammable Substances.—Amongst the more common inflammable substances are ether, acetone, benzene, petrol, naphtha, carbon bisulphide. When solutions containing these substances are to be distilled, they should be treated as described under Ether on p. 62. All these require careful storage (p. 77).

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The vapour from moist calcium carbide is also inflammable. This compound must therefore be kept perfectly dry.

Iodates.—These react in a similar but less vigorous manner as the chlorates (p. 147).

Lead and all its salts are poisonous.

Mercury and all its salts are poisonous, some being exceedingly so. Mercury vapour itself has an injurious effect on man, and when breathed in fairly large quantities, has been known to cause death.

Nitrogen. *Preparation of.*—See Ammonium Nitrite (p. 146).

Nitrogen Chloride has been known to explode when heated alone. It always explodes with considerable violence when heated with many substances, especially organic ones.

Nitrobenzene.—Almost all the aromatic nitro and amido compounds require careful treatment, as do the aliphatic ones to a lesser degree. Nitrobenzene in particular is a very dangerous poison, either in the form of vapour or as liquid. The danger is further enhanced in that symptoms are delayed, often for some hours (compare nitrous oxide), and then rapidly come to a climax. A case is reported of a chemist who spilt some of the liquid on his clothes, took no notice of it and went on with his work. Some hours later he became suddenly ill and ultimately died. Fumes of the other substances act similarly, but less vigorously. The liquid is said to be absorbed through the skin and so poisons the blood, as do nitroglycerin, the nitrophenols, etc.

Nitrogen and Hydrogen Compounds.—All these, with the exception of ammonia, are liable to explode when heated, or when under other conditions.

Nitrogen Iodide in a dry condition will explode when shaken, or if touched ever so lightly, *e.g.* with

a feather. Its bark is, however, much worse than its bite. Moist nitrogen iodide does not explode.

Nitrous Fumes, produced when nitric acid reacts with metals and most organic substances, are poisonous. Their action is usually a delayed one and symptoms do not occur for a few hours, small amounts of the gas producing giddiness and headache; whilst large amounts may be fatal.

When nitric acid is added in considerable excess to alcohol, nothing happens for some minutes; then quite suddenly and with little or no warning, a vigorous action starts and the fumes are forced out of the vessel with great violence. All such reactions should be performed in the fume cupboard.

Nitrous Oxide. *Preparation of.*—See Ammonium Nitrate.

Phosphorus, especially the white (yellow or waxy) variety, is volatile and the fumes are poisonous. See also p. 66.

Phosphorus Hydrides.—Small amounts of these are dangerous, *e.g.* 2 parts per 1000 of phosphine are said to be fatal. Liquid phosphorus hydride is also spontaneously inflammable.

Picric Acid is explosive when in the dry state, and when heated.

Phosphorus Chlorides, as well as the oxychloride, fume in moist air, producing a vapour which attacks the respiratory system and the eyes. Small amounts are dangerous.

Potassium.—See p. 67.

Potassium Chlorate.—See Chlorates.

Potassium Cyanide.—Cyanides and most of the derivatives of cyanogen are very poisonous, both the liquid and the fumes. The symptoms of very slight poisoning are headache, giddiness, a feeling of fulness in the throat and noises in the ears. The solid must not be smelled (see p. 68).

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Potassium Ferrocyanide is not very poisonous. When treated with concentrated acid, it yields either hydrogen cyanide or carbon monoxide, two very poisonous gases.

Potassium Ferricyanide is not very poisonous.

Potassium Permanganate may cause an explosion when heated with, or even when ground with, certain organic substances, *e.g.* glycerine or certain fats, etc.

Sodium.—See p. 69.

Sulphur Dioxide.—Small quantities of this gas—5 parts per 10,000—act as an irritant and cause coughing and sneezing. More concentrated still, the gas is non-respirable.

Toluene.—See Benzene.

Xylene.—See Benzene.

The foregoing has not been written to convey the impression that science is a dangerous subject. A list of risks run by the children in coming to and from school, or in playing in the streets, etc., would be quite as formidable. All that is desired is to point out that certain accidents may occur and that it is necessary to take whatever precautionary measures seem advisable.

First Aid Treatment

Ordinary Cuts and Wounds.—Strictly speaking, no cut or wound sustained in a laboratory is an ordinary one, for there is always the danger that some foreign substance will have entered the cut. This is particularly so in the chemical laboratory and also in the biological laboratory, where, for example, a cut may have been sustained whilst dissecting some animal, possibly a diseased one. Hence it is essential to treat even a very small cut as a possible source of great danger.

Following the precedent set during the war, the wound should be swabbed with *tincture of iodine* on

cotton wool, etc. A preliminary *washing is not necessary* unless the wound is dirty; indeed, it is said to be harmful, since it causes the cells to swell and so prevents the iodine from penetrating. (If the wound is very dirty, however, it should be first washed and thoroughly dried.) A weak solution of iodine should be employed, *i.e.* a 2.5 per cent. solution, since a strong one may cause blistering. When the iodine solution has dried, a sterilized dressing and bandage is applied. All ordinary bleeding, except where a large artery has been cut, will stop with firm application of the bandage. A small boy may become faint if one waits for the bleeding to stop. If an artery has been cut a tourniquet must be applied.

Small cuts can be covered with a solution of collodion instead of a bandage.

Although, as a rule, washing the wound must be avoided, it is sometimes necessary to have to do so, *e.g.* when acid has entered the wound, and the master should use his own discretion when to apply water (see below).

Dry Burns.—There are at least two common alternative methods of treating dry burns.

Method I.—In the modern treatment no oil of any nature is used. *Without touching* the affected part, and *without applying water*, a large sterilized dressing is applied and tied so as to exclude all air. Instead of the dressing a piece of gauze, lint, cotton wool, etc., may be moistened with the aqueous picric acid solution and then bandaged as before. Picric acid relieves the pain very quickly. It should not be used if a large area is affected; in such a case the burn should be treated as under Method II. Its chief disadvantage is that it stains the skin yellow. This stain can be removed, however, by a solution of sodium benzoate (1 gram) and boric acid (1 gram) in 100 c.c. of water.

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Method II.—The old method was to cover the wound with a dressing of carron oil (or some other oil or vaseline). If this treatment is carried out, a strip of linen, etc., should be soaked in the oil and placed over the burn, and bandaged. If the pain is very severe, it can be relieved a little by a repeated application of carron oil. Burns due to molten substances are treated as ordinary burns. If any clothing adheres to the wound, great care must be exercised in its removal. It should not on any account be torn away, but saturated with repeated applications of carron oil and left until the clothing has softened, when it is easily removed. In all cases water must not be used, nor should any blisters be broken. (The subsequent treatment of burns that have had carron oil applied to them is somewhat complicated, owing to the oil making the skin soft.)

Scalds.—The scalded part is placed or bathed in a warm solution of sodium bicarbonate, washed and dried. Afterwards it is treated as an ordinary burn.

Acid Burns.—If at all possible, place the affected part under the tap and turn on the water at full strength. Otherwise wash the burn with a large amount of water. Small amounts are dangerous, owing to the heat of dilution. When most of the acid has been removed in this manner, wash the wound with a solution of sodium bicarbonate or sprinkle solid bicarbonate over it. This neutralizes any remaining acid. On no account should the alkali be put on the acid until after washing, for the heat of neutralization is considerable. The wound is then carefully dried and treated as an ordinary burn.

Alkali Burns.—These are treated as acid burns except that a dilute acetic acid solution (1 per cent.) is used in place of the sodium bicarbonate.

Bromine Burns.—Wash the burn first of all with

a solution of sodium bicarbonate and follow this with alcohol, or benzene. Finally, dry the wound with absorbent wool and treat as an ordinary burn.

Phosphorus Burns.—These burns are usually of a severe nature and, after a preliminary dressing of the burn, the injured pupil should be sent to the doctor. Such a burn must not be treated as an ordinary one, since phosphorus is very soluble in carron and other oils. Thus the effect of using an oil is to spread any remaining phosphorus over a greater surface.

The burn should be well washed with water so that no phosphorus remains, and then with a piece of absorbent wool soaked in dilute silver nitrate. All air should be excluded by a tight bandage.

Clothes on Fire.—In laboratories where much organic work is carried out there is a real danger of fire. Fire buckets full of water and of sand should be at hand. If the clothing catches fire, the flames must be smothered immediately. For this purpose some keep an old blanket. If no such thing is near, the master may use an old coat, rug or anything of that nature which is at hand. Afterwards treat any burns as before. Also watch carefully for any signs of shock or faintness and treat accordingly.

✓ **Suffocation owing to Gases.** *General Treatment.*—Suffocation of a serious nature, especially if the boy is unconscious, is treated as in artificial respiration after drowning. The patient should be taken out of the laboratory into the fresh air, and laid on the ground on some cover such as a coat, etc., his clothing having been loosened. The patient must be laid face downwards, resting the left side of the face on the ground. His tongue should be drawn well forward by holding the tip in a handkerchief between the finger and thumb. The arms from the shoulder to the elbow should be extended sideways, and from

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the elbows to the fingers at right angles to the upper arm. The rescuer kneels astride the patient, facing the front, and places his hands in the small of the back with the thumbs parallel pointing towards the head and his fingers spread out as much as possible on each side of the body. A gentle pressure is exerted by the rescuer, who leans forward, so allowing his weight to fall steadily over his hands and forcing the body of the patient to the ground. Pressure is then released by the rescuer assuming an upright position without removing his hands. This forward and backward movement is repeated at the rate of fifteen times per minute until the patient recovers. Artificial respiration must be carried out until a doctor pronounces it useless, or until the patient recovers.

Liquid must not on any account be given whilst the patient is unconscious.

In less severe cases, where the pupil is gasping for breath, is giddy, or loses the power of his legs, fresh air is essential, and the chest and face should be slapped with a cold wet towel. The method outlined above can be employed, if desired, since it tends to clear the lungs of the gas.

After all gassing cases, the pupil should be allowed absolute rest for a few hours.

Traces of Chlorine or Bromine Inhaled.—

Where this is not serious, allow the pupil to smell ammonia, ammonium carbonate, or alcohol. A gargle of sodium bicarbonate is beneficial. Indeed, whenever chlorine or bromine is being prepared, it is advisable to have a beaker of such a solution at hand.

If much gas has been inhaled apply the general treatment for cases of gassing and, in addition, allow the patient to smell one of the above substances, preferably ammonium carbonate.

Sulphur Dioxide.—Apply the general treatment

and, in addition, it is recommended that a seidlitz powder be given when the patient is conscious.

Other Gases.—Apply the general treatment.

Bromine Vapour in the Eye.—This is both painful and dangerous. The eye should be washed first with the alkaline eye-wash, and then with water by means of an eye-bath. After this add a drop of castor oil in the corner of the eye to relieve any pain.

Instead of this, for slight cases, the alcohol bottle may be held under the eye so that alcohol vapour can enter, but care must be taken that no liquid alcohol gets into the eye.

Acid in the Eye.—Wash the eye with water by means of a wash bottle, carefully directing a slow stream into the eye. Alternatively, the face can be immersed in water and the eye opened and closed. Then apply the alkaline eye-wash. Afterwards relieve the pain with castor oil as above.

Alkali in the Eye.—This is treated in the same way, except that a weak boric acid solution is employed in place of the alkaline eye-wash.

Eye Injuries. General Treatment.—In all cases involving eye injuries, light should be excluded by a bandage and the patient sent to the doctor. The eye is much too delicate and precious an organ for an amateur to deal with except temporarily.

Liquids on Skin.—Splashes of aniline, nitrobenzene and other nitro and amido derivatives must be washed off immediately with water. Special attention must be paid to any splashed clothing. If badly splashed, it should be removed and washed before it is worn again.

Fainting is a common sequence to most injuries received by the schoolboy. If signs of this are shown—that is, if the boy becomes restless, or if beads of perspiration gather on the forehead or upper lip—he should be made to sit on a chair in the open. All

clothing, especially the collar, must be loosened immediately and his head placed between his knees until he flushes red. Smelling salts should be used, and when he becomes conscious, but not until then, he may be given a little cold water or some stimulant, such as a few drops of sal volatile in water, to drink. If unconscious, the patient should be laid on his back in the open air with the head on one side and smelling salts applied to his nose. He should be kept as warm as possible, by overcoats, etc., and care should be exercised, when he appears to have recovered, that he does not have a relapse.

Electric Shock.—In this case the rescuer must think of himself first of all if the victim is still in contact with the live wire. He must be insulated, before he touches the victim, by standing on a piece of wood or some non-conductor, and by wearing rubber gloves, or by covering his hands with some rubber material. The victim is powerless to move and should be pushed away from the wire somewhat vigorously. If the rescuer is not in a position to touch the victim, he should push him away with a piece of *dry* wood, a walking stick, broom handle, etc. The wood must be dry and for safety should be grasped by a dry cloth, such as the inside of the jacket or anything else at hand.

When free from the wire, or in cases of severe shock obtained from a battery, the patient should be made to lie down and kept warm by hot water bottles or blankets, artificial respiration being applied if necessary.

The First Aid Box.—Every chemical laboratory should contain a first aid box of its own, which should not be removed from a fixed and well-known place. Such a box can be made in any school workshop. It should be about 2 ft. by 1 ft. by 8 in., and divided into suitable compartments for each

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bottle. No lock is necessary; indeed, it is advisable not to have one, since the key is so often lost just when wanted. Near the box should be hung brief, but adequate, instructions on the treatment of the common injuries. The box should contain the following substances:

Acetic Acid.—For alkali burns.

Add 3 c.c. of glacial acetic acid to 250 c.c. of water.

Acid Eye-Wash.—Label the bottle—For alkalies in eye—to avoid confusion.

Dissolve 1 gram of boric acid in 100 c.c. water.

Alcohol.—A bottle containing about 100 c.c. of ordinary rectified spirit.

Alkali Eye-Wash.—Label the bottle—For acids in eye.

Dissolve 3 grams of sodium bicarbonate in 100 c.c. water.

Bandages.—An ample supply of various sizes of bandages is required.

There should be included one or two triangular bandages.

Benzene.—A small bottle, as purchased, is required.

Boric Acid.—A saturated solution is sometimes used to relieve the pain due to wounds, etc.

Carron Oil.—Mix together equal volumes of lime water and linseed oil. „Shake the bottle vigorously until the solutions have emulsified and again each time before use. Olive oil may be used in place of the linseed oil. The efficacy of the carron oil is increased if approximately 1 gram of phenol is dissolved in 100 c.c. of carron oil.

Castor Oil.

Collodion.—The preparation of this is somewhat troublesome; hence it is best to purchase the collodion ready made. It is a solution of pyroxylin (gun cotton), in ether and absolute alcohol. Flexible collodion is better than ordinary collodion.

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Dressings.—A few sterilized dressings should be purchased, including burn dressings.

Eye-Bath.

Gauze, Medicated.

Iodine Solution.—Dissolve 2·5 grams of potassium iodide in a small amount of water and add 2·5 grams of iodine. When the iodine has dissolved, make up the volume to 100 c.c. with spirit.

Lint.

Olive Oil.

Picric Acid.—Dissolve 1 gram of the solid in 100 c.c. of water. (See note on Picric Acid, p. 108).

Pins.—A supply of safety pins of various sizes is required.

Phenol.—Dissolve 5 grams of phenol (carbolic acid) in 100 c.c. of water. This may be used as an antiseptic in place of iodine.

Plaster.—A roll of self-adhesive zinc plaster, $\frac{1}{2}$ -in. wide, is useful.

Sal Volatile.—This is a mixture of oil of nutmeg, oil of lemon, alcohol, water, ammonium carbonate and ammonia, and is best purchased ready made from the druggist. A 2-ounce bottle is sufficient for a considerable time. It should be well-stoppered.

Scissors.

Seidlitz Powder.

Silk, Oiled.—A packet of oiled silk is useful in case of very serious injury.

Silver Nitrate.—Dissolve approximately 1·7 grams of the crystals in 100 c.c. water.

Sodium Bicarbonate.—Prepare 250 c.c. of a saturated solution. About 20 grams of the solid is required for this amount of water.

Tweezers.—A pair of tweezers.

Wool, Absorbent.

The stock should be periodically examined to see whether everything is fit for immediate use.

APPENDIX I

NOTES FOR THE LABORATORY ASSISTANT IN CHEMISTRY

Ascertain which of the undermentioned systems is in use in your laboratory (see p. 52), and prepare the solutions according to the appropriate column. The quantities given are to make a final volume of one litre in distilled water.

Substance.	Arbitrary System.	2. Normal System.	3. Normal System.	
Acetic Acid, Bench, conc.	330 c.c.	330 c.c.	330 c.c.	Of glacial acetic.
Acetic Acid, dil.	50 c.c.	116 c.c.	174 c.c.	Ditto.
Alcohol, 60 per cent. (etc.)	666·6 c.c.	666·6 c.c.	666·6 c.c.	Of rectified spirit.
Ammoniacal Cuprous Chloride	Special Instructions, p. 55.			
Ammonium Acetate	100 gr.	154 gr.	154 gr.	
Ammonium Carbonate	Special Instructions, p. 55.			
Ammonium Chloride	100 gr.	107 gr.	107 gr.	
Ammonium Hydroxide, conc.	As purchased.			18·5 N.
Ammonium Hydroxide, dil.	300 c.c.	108 c.c.	162 c.c.	Of liquor ammon. fortis.
Ammonium Molybdate	Special Instructions, p. 56.			
Ammonium Oxalate	25 gr.	35·5 gr.	35·5 gr.	Not very soluble.
Ammonium Sulphide	As purchased or 330 c.c. of this.			
Ammonium Sulphocyanide	10 gr.	15 gr.	15 gr.	Very delicate reagent.
Aqua Regia	3 parts by vol. conc. HCl to 1 HNO ₃ .			
Barium Chloride	100 gr.	122 gr.	122 gr.	
Barium Nitrate	50 gr.	65 gr.	65 gr.	Not very soluble.
Bromine Water	A saturated solution.			Approx. N/2.
Calcium Chloride	50 gr.	55 gr.	55 gr.	Using fused solid.
	100 gr.	110 gr.	110 gr.	Using crystal.
Calcium Hydroxide	Special Instructions, p. 60.			Approx. N/22.

Substance.	Arbitrary System.	2. Normal System.	3. Normal System.	
Calcium Sulphate . . .	Special Instructions, p. 60.			Approx. N/35.
Chlorine Water . . .	A saturated solution.			
Cobalt Nitrate . . .	100 gr.	145 gr.	145 gr.	
Dimethylglyoxime . . .	Special Instructions, p. 62.			
Diphenylamine . . .	Special Instructions, p. 62.			
Fehling's Solution . . .	Special Instructions, p. 62.			
Ferric Chloride . . .	100 gr.	90 gr.	90 gr.	
Ferrous Sulphate . . .	20 gr.	20 gr.	20 gr.	Unstable.
Fusion Mixture . . .	40 gr. Na_2CO_3 to 50 gr.			K_2CO_3 .
Hydrochloric Acid, conc.	As purchased.			10.2 N.
Hydrochloric Acid, dil.	300 c.c.	199 c.c.	298 c.c.	Of conc.
Indicators . . .	Special Instructions, p. 75.			
Lead Acetate . . .	100 gr.	190 gr.	190 gr.	
Magnesium Sulphate . .	100 gr.	123 gr.	123 gr.	
Mercuric Chloride . . .	50 gr.	27 gr.	27 gr.	Not very soluble.
Nessler's Reagent . . .	Special Instructions, p. 65.			
Nitric Acid, conc. . . .	As purchased or 500 c.c.			
Nitric Acid, dil. . . .	200 c.c.	127 c.c.	190 c.c.	Of conc. acid.
Platinum Chloride . . .	50 gr.	41 gr.	41 gr.	Expensive make N/10.
Potassium Bichromate . .	50 gr.	49 gr.	49 gr.	
Potassium Chromate . . .	50 gr.	97 gr.	97 gr.	
Potassium Ferricyanide .	50 grams freshly prepared.			Unstable.
Potassium Ferrocyanide .	50 gr.	211 gr.	211 gr.	See p. 68.
Potassium Iodide . . .	100 gr.	33 gr.	33 gr.	Very expensive. An N/5 solution.
Potassium Permanganate .	1 gr.	3 gr.	3 gr.	Not very soluble.
Potassium Sulphocyanide .	10 gr.	19.5 gr.	19.5 gr.	Very delicate re-agent.
Silver Nitrate . . .	50 gr.	34 gr.	34 gr.	Expensive.
Sodium Acetate . . .	200 gr.	272 gr.	272 gr.	
Sodium Cobaltinitrite . .	Special Instructions, p. 70.			
Sodium Hydroxide . . .	150 gr.	80 gr.	120 gr.	
Sodium Nitroprusside . .	25 gr.	25 gr.	25 gr.	Unstable.
Sodium Phosphate . . .	100 gr.	119 gr.	119 gr.	
Stannous Chloride . . .	Special Instructions, p. 71.			
Sulphuric Acid, conc. . .	As purchased or 330 c.c.			
Sulphuric Acid, dil. . .	130 c.c.	56 c.c.	84 c.c.	Of conc. acid.

APPENDIX II

LIST OF BENCH APPARATUS IN CHEMISTRY

The following list suggests the apparatus that may be kept in each bench cupboard or drawer. The letters E and A indicate the apparatus which is useful in an elementary or an advanced laboratory respectively. The most useful size is indicated thus * :

- E.A. 3 Beakers, 1 150-c.c., 1 250-c.c.*, 1 400-c.c.
- E.A. 1 Beehive shelf, earthenware, $7\frac{1}{2}$ cm. diam.
- A. 1 Blowpipe, mouth. Black's.
- E.A. 2 Boiling tubes, 7 in. by 1 in.
- E.A. 1 Bunsen burner, about 5 in. high, with 2 ft. of $\frac{5}{16}$ in. indiarubber tubing.
- A. 1 Burette, 50 c.c. capacity, with stand.
- A. 1 Charcoal block, 3 in. by 1 in. by 1 in.
(Corks and rubber stoppers. A suitable assortment of 20 corks consists of 1 $1\frac{1}{4}$ -in., 1 1-in., 3 $\frac{7}{8}$ -in., 3 $\frac{3}{4}$ -in., 8 $\frac{5}{8}$ -in., 4 $\frac{1}{2}$ -in.)
- E.A. 2 Crucibles and lids, 1 17-c.c.*, 1-25 c.c.
- E.A. 1 Pair of crucible tongs, 6 in. long. (Tongs of nickel can be purchased for 1s. 6d.)
- E.A. 1 Cylinder, graduated, 100 c.c.
- A. 1 Desiccator, 8 by 8 cm.
- E.A. 2 Evaporating basins, 1 120-c.c., 1 200-c.c.
- A. 100 Filter papers, 11 cm.
- E.A. 1 Filter stand.
- E.A. 2 Flasks, conical, 1 100-c.c., 1 250-c.c.*
- A. 2 Flasks, distilling, 1 100-c.c.*, 1 250-c.c.
- A. 2 Flasks, graduated, 1 100-c.c.*, 1 250-c.c.
- E.A. 1 Flask, round bottom, 350 c.c.
- E.A. 2 Funnels, 3 in. diam.

- E.A. 1 Funnel thistle, 8 in. or 12 in. long.*
- E. 8 Gas-jars, with ground flange, 8 in. by 2 in.
- E. 3 Gas-jars slides, 3 in. diam.
- E.A. 1 Glass rod, rounded at each end, 7 in. long.
 - A. 2 Litmus paper books, 1 red, 1 blue.
- E.A. 1 Mortar and pestle, porcelain, glazed outside and partly inside, 8 cm. diam.
 - A. 2 Pipettes, 1 10-c.c., 1 25-c.c.
 - A. 1 Piece platinum wire, 2 in. long, mounted on glass rod.
- E.A. 1 Pneumatic trough, earthenware, 10 in. by 4 in. high.
- E.A. 2 Retorts, 1 125-c.c.*, 1 350-c.c.
- E.A. 1 Retort stand, 17 in. rod, base 6 in. by $3\frac{1}{2}$ in., with 2 rings, 1 $1\frac{1}{2}$ -in. diam., 1 3-in. diam., and 1 clamp, length of jaw, $2\frac{1}{2}$ in.
 - A. 1 Sand tray, 7 in. diam.
 - A. 1 Spatula, bone, 3 in. long.
- E.A. 12 Test-tubes, 6 by $\frac{5}{8}$ in.*, or 5 by $\frac{5}{8}$ in.
- E.A. 1 Test-tube stand, with 12 holes and pegs.
- E.A. 1 Test-tube brush.
- E.A. 1 Triangle, 2 in. sides (Vitreosil on nickel-chrome wire).
- E.A. 1 Tripod stand, triangular top, 8 in. high, length of side, 6 in.
- E.A. 1 Wash bottle.
- E.A. 2 Watch glasses, 2 in. diam.
- E.A. 1 Wire gauze, 4 in. by 4 in., with asbestos centre.

APPENDIX III

CHART OF EXPERIMENTS IN PRACTICAL CHEMISTRY

EXPERIMENT.	NAME.	Argent, D.	Barrett, M.	Chapman, P.	Green, W.	Hill, C.	Jones, K.	Page, J.	Saunders, K.	Thomas, A.	Walls, J. W.	Wood, F.
VOLUMETRIC ANALYSIS.												
<i>A. Acidimetry and Alkalimetry</i>												
Determine strength of given HCl		X	X	X	X	X	X	X	X	X	X	X
----- etc. -----												

<i>B. Potassium Permanganate</i>												
Preparation of an N/10 soln. of KMnO_4		X	X	X	X	X	X	X	X	X	X	X
----- etc. -----												

<i>C. Silver Nitrate</i>												
Preparation of an N/10 soln. of AgNO_3		X	X	X	X	X	X	X	X	X	X	X
----- etc. -----												

<i>D. Iodimetry</i>												
Preparation of an N/10 soln. of Iodine		X	X	X	X	X	X	X	X	X	X	X
----- etc. -----												

GRAVIMETRIC ANALYSIS.												
Determine % of H_2O in blue Vitriol		X	X	X	X	X	X	X	X	X	X	X
----- etc. -----												

INORGANIC PREPARATIONS.												
Preparation of PCl_5 *		X	X	X		X		X	X			X
----- etc. -----												

PHYSICAL CHEMISTRY.												
Find the density of CO_2					X			X		X		X
----- etc. -----												

ORGANIC CHEMISTRY.												
Show the presence of Nitrogen*		X	X	X	X					X	X	
----- etc. -----												

Notes.—1. When an experiment is commenced make a diagonal mark in the appropriate column. 2. When the experiment has been completed, and the account of it initialed by the teacher, draw the opposite diagonal. 3. Experiments marked * must not be commenced until individual permission has been obtained.

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